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CONTAMINANTS IN WATER TREATMENT PLANT CHEMICALS

September, 1985

HAZARDOUS CONTAMINANTS
AND STANDARDS BRANCH
135 ST. CLAIR AVENUE WEST
TORONTO, ONTARIO M4V 1P5

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CONTAMINANTS IN WATER
TREATMENT
PLANT CHEMICALS

by

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SUMMARY

The data from the program indicate that contaminants currently appear in water treatment chemicals at low enough levels that they offer little hazard to the health of consumers. This is supported by results of recent surveys of treated drinking water; very low levels of a small number of compounds were found in the treated waters and their presence appeared not to be a result of contamination in treatment chemicals. Contaminant concentrations in treatment chemicals would have to rise considerably before they would become cause for concern.

It is recommended that water treatment plant chemicals be monitored for contaminants with the emphasis on the primary treatment chemicals such as alum, ferric chloride and fluoridation chemicals because of their more extensive use. Chlorine and polymers cannot currently be analysed since available methods are not applicable.

Quality tests for water treatment chemicals (which should be undertaken by plant operating personnel) are outlined in Appendix 5.

Differences in physical properties between various chemicals, especially alums, may be sufficient to cause operational problems during application to the water treatment process. Improper handling and storage of some chemicals may affect their performance.

RECOMMENDATIONS

1) Quality control checks should be carried out on chemicals upon receipt at water treatment plants before acceptance of a shipment; if possible, for alum, these checks should include simple tests at the plant, such as pH, colour and colour/turbidity. Certain specifications should be provided by the manufacturer and should be compared to 'standard' specifications, such as those proposed by the AWWA* for water treatment chemicals (Appendix 5). Chemicals with specifications outside the recommended range should not be accepted.

2) Unless in-plant testing and/or specification comparisons indicate(s) an increase in the number of abnormal lots of chemicals, comprehensive monitoring need only be undertaken once every five years. Checks recommended in Appendix 5, should provide a good indication of quality control problems or changes in production techniques occurring during the manufacturing process.

3) Plant management must be made fully aware of the procedures or regulations for the handling and proper use of water treatment chemicals. Chemicals received and stored at water treatment plants must be kept under conditions that prevent or minimize deterioration. Chemicals must be prepared and applied to the treatment process in the correct manner, to ensure their effectiveness is prevent or minimize detenoration.

4) Since plant supervisors and personnel are directly responsible for the quality of chemicals accepted and used at water treatment plants, it is important that all training and instruction courses for such personnel (e.g. Ministry of the Environment, Training & Certification courses) emphasize instruction in the appropriate analytical testing methods and handling procedures for plant chemicals. Suggestions for on-site tests are given in Appendix 5.

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* AWWA - American Water Works Association

5) Results of quality control checks of treatment chemicals should be kept at water treatment plants for a period of at least five years; duplicate records should be forwarded to a central file (Ministry of the Environment, Water Resources Branch, Drinking Water Section) for cross-referencing. In this manner, trends of deteriorating or increasing quality of chemicals produced by various manufacturers could be recognized and appropriate action taken.

6) Research into the development of analytical techniques for the examination of water treatment plant chemicals is to be encouraged. This is particularly important to detect and identify organic contaminants in such chemicals. Standardized analytical protocols for the examination of treatment plant chemicals for specific contaminants would follow.

WATER TREATMENT CHEMICALS

INTRODUCTION

Substances potentially harmful to the health of consumers may be present in drinking water because of contamination of the raw water source, or because they are introduced during the water treatment process. This program investigated the chemicals used in water treatment for the possible presence of such undesirable contaminants.

The study was designed to determine:

a) the extent to which chemicals used in water treatment may be contaminated with heavy metals, organic substances etc.

b) the variation in quality, as demonstrated by specific gravity, colour, turbidity etc. of treatment chemicals, and the extent to which this variation may affect the treatment process.

c) the actions which are required to establish effective procedures for the delivery, examination and use of water treatment chemicals. Such procedures may ensure that such chemicals are manufactured with acceptable quality so that future programs of this type may only be necessary on an intermittent basis.

d) the necessity for the continued monitoring of such chemicals.

e) the frequency with which water treatment chemicals should be monitored, and the methods.

Additionally, some further areas for study were revealed as a result of some interesting developments which occurred during the course of the investigation.

The initial effort was limited to the examination of water treatment chemicals at the manufacturing plants, for potentially hazardous substances. However, the manufacturers viewed this investigation with some misgivings, in case the findings should reveal significant quality differences with respect to contaminants, between the products of various manufacturers. The study plan was modified as a result.

The program consisted of the following components:

1. The development of a list of the most frequently used chemicals that are employed in water treatment processes in Ontario.
2. The compilation of a list of all manufacturers whose products were examined, along with the production processes where appropriate.
3. An analytical investigation of each chemical for trace metals and organic compounds.
4. The physico-chemical analysis of the chemicals where appropriate; results would show the colour, specific gravity, turbidity and pH; in the case of liquid alum and ferric chloride, pH was determined both directly and in a 1% solution.
5. The development of broad recommendations for a future monitoring program, after the examination of all the chemicals; this would be intended to detect any future changes in quality in manufactured chemicals.
6. The development of a guide for plant supervisors and operators for assessing chemicals upon arrival at treatment plants, including precautions to ensure the safe use of chemicals and prevent loss of strength.

SAMPLING PROCEDURES AND SAMPLING SITES

1. SAMPLING PROCEDURES

As originally planned, visits were to be made to the manufacturers' plants to view their manufacturing processes and sample the treatment chemicals. Only a few plants were sampled since problems with this approach were encountered almost immediately.

This direct approach was therefore abandoned and alternate methods of sampling were investigated. Accordingly, the location of the sampling point was changed from the manufacturer's site to the water plant itself.

In this way, representative samples of the chemicals could be obtained whenever they were required, in the condition they were received at the water plant.

This new procedure had the added advantage that the chemicals could now be monitored "as delivered"; any contamination that might have occurred in transit to the water plants, by the use of non-dedicated carriers e.g. tanker trucks, previously used to transport other chemicals, or that may have occurred subsequent to manufacture, during storage and/or shipment would be detected. Further, this system obviates a bias which would have existed had the original sampling protocol been followed. Of the four manufacturers that produce treatment chemicals, one has a 75% share of the market, while the three others divide the remaining market approximately equally among themselves. Under the previous plan, each manufacturer would have supplied the same amount of material for test, even though one fills three quarters of the market requirements i.e. the ratio of the amount of material tested to that actually supplied for treatment was inadequately low. By sampling directly at the water plants, the products of the manufacturer supplying the largest quantity of chemicals, were automatically sampled more frequently, as bona fide sampling protocols would dictate.

Samples were categorized as primary coagulants, treatment aids (coagulant aids and water conditioners), raw and treated waters, sludges (both old sludges from settling basins and fresh sludges from settled backwashes) and fluoridation chemicals. The materials sampled are shown in Table 1. Treatment plant chemical and sludge samples were taken in wide-mouthed, acid-washed plastic bottles, and were not preserved. Water samples for metal analysis were taken in acid-washed one litre (L) glass bottles with two millilitres (mL) of 50% nitric acid per litre added for preservation; for mercury analysis, bacteriological sample bottles were used, the sample being preserved by the addition of 1 mL of concentrated nitric acid and 0.5 mL of saturated potassium dichromate solution (1). Water samples for other analyses were taken in 1 L glass bottles with no preservation.

TABLE 1

WATER TREATMENT CHEMICAL CATEGORIES

PRIMARY COAGULANTS -	Aluminum sulphate - solid Aluminum sulphate - liquid Ferric chloride Sodium aluminate
TREATMENT AIDS -	Calcium oxide (unslaked lime) Sodium bicarbonate Sodium carbonate (soda ash) Sodium hydroxide Activated carbon Cat Floc T
WATER -	Raw, untreated water Finished, treated water
SLUDGE -	Usually a mixture of old sludge, from settling basins and new sludge from settled backwashes
FLUORIDATION CHEMICALS -	Sodium silicofluoride Hydrofluorosilicic acid

2. SAMPLING SITES

The first samples of treatment chemicals were those collected at the manufacturing plants; single, grab samples of alum were collected from two manufacturers while ferric chloride was sampled at only one. Subsequently a sampling program was drawn up which would entail the collection of samples from as many water plant locations as possible over the envisaged period of the program.
The water plants shown in Table 2 were selected on the basis of the following criteria:

1. The plants received treatment chemicals from a good cross-section of the chemical manufacturers; the quantities of chemicals supplied to them were also considered.

2. The plants had large flow rates, because the greater volume of water treated resulted in quicker turnover of chemicals; this ensured that the latest batches of chemicals produced by the manufacturers would be the ones being sampled for the program; further, the larger the plant, the more complete the treatment process, and thus the greater the number of chemicals used.

3. The plants selected represented both lake and river supplies, in various parts of the Province.

Table 3 shows the manufacturers who supplied chemicals to the water plants included in the study.

ANALYTICAL METHODS

1. PHYSICAL - Colour and turbidity of samples were examined visually and measured photometrically with a Hach DR2 spectrophotometer, and any gross foreign contamination was noted; the pH was determined electrometrically, undiluted and in 1% solutions prepared in distilled water, on a Fisher Accumet Model 325 (expanded scale) pH meter; specific gravity was determined by weighing using a Sauter balance, model

TABLE 2

WATER PLANTS SAMPLED FOR TREATMENT CHEMICALS

Plant	Location	Source of Supply	Capacity (1000m^3)/day
Stage 2			
Caldwell W.S.*	Verner	Veuve River	1.059
R.C. Harris WTP**	Toronto	Lake Ontario	1000.12
R.L. Clark WTP	Toronto	Lake Ontario	454.6
Stage 3			
Elgin Area W.S.	Yarmouth Twp.	Lake Erie	45.5
R.H. Neath WTP	Owen Sound	Georgian Bay	30.004
Sarnia W.S.	Sarnia	Lake Huron	181.84
Goderich WTP	Goderich	Lake Huron	12.001
Port Elgin WTP	Port Elgin	Lake Huron	8.706
R.L. Clark WTP	Toronto	Lake Ontario	454.6
Grand Bend W.S.	Grand Bend	Lake Huron	168.2
Stage 4			
Easterly WTP	Scarborough	Lake Ontario	454.6
Lindsay WTP	Lindsay	Scugog River	22.730
Kenora WTP	Kenora	Lake of the Woods	26.594
R.C. Harris WTP	Toronto	Lake Ontario	1000.12
Arnprior WTP	Arnprior	Madawaska River	15.456
Cornwall WTP	Cornwall	Lake St. Lawrence	100.012
Hawkesbury WTP	Hawkesbury	Ottawa River	18.184
Brittania WTP	Ottawa	Ottawa River	247.302

* WS - water system

**WTP - water treatment plant

TABLE 3

MANUFACTURERS OF SAMPLED WATER TREATMENT CHEMICALS

Alcan (Ottawa, Ont.)	Alum (aluminum sulphate)
Allied Chemical (Thorold, Ont.)	Alum (aluminum sulphate)
Allied Chemical (Valleyfield, Que.)	Alum (aluminum sulphate)
" " "	Sodium bicarbonate
Border Chemical (Winnipeg, Man.)	Alum (aluminum sulphate)
Calgon Corporation (Brampton, Ont.)	Cat Floc T (polymer)
Canadian Industries Ltd. (Courtwright, Ont.)	Hydrofluorosilicic acid
" " "	Sodium carbonate
Domtar Ltd. (Beachville, Ont.)	Unslaked Lime
Handy Chemicals (England)	Sodium aluminate
Stauffer Chemicals (Westport Conn., USA)	Sodium carbonate
Superfos (Denmark)	Sodium silicofluoride
Diversey Environmental Products (Clarkson, Ont.)	Ferric chloride
Eaglebrook Environmental Corp., (Toronto, Ont)	Ferric chloride
Canadian Industries Ltd.	Sodium hydroxide
Imperial Chemical Industries (Wilmington, Del., USA)	Sodium hydroxide
Atkemix Inc., (Brantford, Ontario)	Activated carbon

SD1600T. Electron microscope studies were carried out using a transmission type Siemens electron microscope, model 102.

2. CHEMICAL - Analyses for trace metals and specific organic chemicals was carried out using standard preparatory techniques followed by measurement by atomic absorption, emission spectrography, gas chromatography and spectrophotometric colorimetry; analyses were generally carried out according to the methods prescribed in the Handbook of Analytical Methods for Environmental Samples, published by the Laboratory Services Branch, Ontario Ministry of the Environment(1). However, due to the nature of some of the samples, ad hoc modifications of the methods were necessary, along with the aid of special standards.

For some sample types, the available methods of analysis were not suitable, and results were not obtained. For other types of sample, severe interference with the analysis was encountered and, either no result was obtained or the accuracy of the result was questionable. Results with very broad confidence limits or results such as "less than 300 units" etc. were normally included in the latter category. Such results have been included in the discussion of the results, but should be regarded as only semi-quantitative. Chlorine and the polymers (except Cat Floc T) were not analysed because analysis was difficult and interference-prone; the dosage at which these substances would normally be used, however, is so low, that any contaminant would have to form a high percentage of the material to become a hazard in the finished water. Precursor materials, used to manufacture the water treatment chemicals were not tested because of the complex preparative and analytical techniques that would be required, their highly corrosive effect on laboratory apparatus, and the hazard to laboratory personnel.

PROGRAM STAGES

STAGE 1

In this stage, the samples of treatment chemicals were obtained from the manufacturer's plants; Ministry personnel did not perform the actual collection. Lack of control over the sampling procedures could have resulted in unrepresentative samples and this must be taken into account when considering the results.
Aluminum sulphate from two manufacturers, and a sample of ferric chloride were subjected to analyses for ten trace metals, asbestos fibres and other particulates, and specific gravity. (Table 4)

STAGE 2

The sampling of treatment chemicals, delivered to the water plants, was initiated in this stage. The analysis for trace metals was expanded to thirty one parameters; analyses methods for some trace metals, namely calcium, gallium, germanium, indium, magnesium, mercury, silicon, strontium, titanium and zirconium were tentative during the initial portions of this stage, but were subsequently adopted as satisfactory during latter stages. SE/GC* and specific gravity investigations were carried out on some samples of the primary coagulants. Electron microscope analysis was attempted but discarded due to analytical difficulty and high cost. Waters and sludge from the R.C. Harris plant only were analysed for metals, but waters and sludges from this plant plus R.L. Clark and Verner were analysed by SE/GC. Analyses carried out are shown in Table 4, Stage 2. Samples of hydrofluorosilicic acid were analysed by SE/GC only, as in Stage 1.

*SE/GC - solvent extraction/gas chromatography.

Results from this stage would indicate not only the degree to which treatment plant chemicals could be contaminated with specific substances, but also whether the raw water contained such substances, their probable path through the treatment process and their concentration in the final product water.

STAGE 3

It became evident that modifications to the analytical program were necessary, because in some areas of analysis difficulties were encountered due to the nature of the samples and some specific analyses had to be abandoned.

Thus, electron microscope analysis was discontinued in the case of primary coagulants; raw and treated water samples were analysed instead.

SE/GC analysis of raw and treated water samples, was discontinued because the results were consistently negative; it was, however, continued for the primary coagulants, the water treatment plant sludges and the fluoridation chemicals.

Additional tests were also undertaken; the primary coagulants, water plant sludges and treatment aids were analysed for trace organics by solvent extraction, followed by IR scans.* They were also examined for percentage moisture, loss on ignition and total dissolved carbon by a carbon analyser. Raw and treated waters were analysed for general chemistry and total carbon. Seven water treatment plants were included in this stage of the program. Because of the significance and toxicity of mercury, raw and treated waters were examined for this element by flameless atomic absorption, for more sensitive analysis; water samples were also analysed for general chemical parameters, such as hardness, alkalinity, chloride etc.

The complete list of analysis carried out on the sample groups during Stage 3, is shown in Table 4.

* IR scans = infrared spectrophotometry scans

STAGE 4.

Reappraisal of stage 3 resulted in the elimination of analyses where appropriate methods could not be developed, or where inconclusive results had been obtained; solvent extraction/I-R spectrophotometry analysis was therefore phased out during this stage.

Analyses of water plant sludges led to questionable results, when it was discovered that water treatment plants had switched coagulants and dosage rates depending upon conditions in the source water. This lead to a certain loss of control over the study, because the actual source of contaminants in the sludge could not then be determined. Studies of metals in hydrofluorosilicic acid were abandoned, when it was found that acid caused excessive corrosion of the analytical equipment.

The electron microscope analysis of raw and treated waters was also discontinued.

The analytical components of Stage 4, which are shown in Table 4, was the final form of the program.

TABLE 4: ANALYSES CARRIED OUT ON VARIOUS TREATMENT CHEMICALS, WATERS AND WATER PLANT SLUDGES

	Analyses	Primary Coagulants	Treatment Aids	WTP Raw/Treated Waters	WTP Sludge	Fluoridation Chemicals
STAGE 1	Trace Metals	List A1				
	Physical Properties	List B1				
	Solvent Extraction/ Gas Chromatography					List C
	Electron Microscope	List D				
STAGE 2	Trace Metals	List A2		List A2	List A2	
	Physical Properties	List B1				
	Solvent Extraction/ Gas Chromatography	List C		List C	List C	List C
	Electron Microscope	List D				
STAGE 3	Trace Metals	List A2	List A2	List A2	List A2	List A2
	Physical Properties	List B1				
	Solvent Extraction/ Gas Chromatography	List C			List C	List C
	Electron Microscope			List D		
	General Chemistry			List E		
	Carbon Analyser	List F	List F	List F	List F	
	Mercury			List G		
	Loss on Ignition	List H2	List H2		List H2	
	Solvent Extraction/IR	List J	List J		List J	
STAGE 4	Trace Metals	List A2	List A2	List A2	List A2	
	Physical Properties	List B2				
	Solvent Extraction/ Gas Chromatography	List C				List C
	General Chemistry			List E		
	Carbon Analyser	List F	List F	List F	List F	
	Mercury	List G	List G	List G		
	Loss on Ignition	List H1			List H2	
	Solvent Extraction/IR	List J	List J		List J	

TABLE 4, Cont'd

List A
Trace metals
Cadmium
Chromium
Copper
Nickel
Lead
A1 Manganese
Zinc
Cobalt
Tin
Molybdenum
Barium
Mercury
Iron
A2 Silver
Aluminum
Arsenic
Beryllium
Bismuth
Boron
Zirconium
Calcium
Gallium
Germanium
Indium
Magnesium
Tellurium
Silicon
Antimony
Strontium
Titanium
Vanadium

List B
Physical Properties
B1 Specific Gravity
Turbidity
pH
B2 % Alumina
% Free Acid
Colour/Turbidity

List C
Solvent Extraction/
Gas Chromatography
2,4-dinitrotoluene
2,6-dinitrotoluene
Trinitrotoluene
Other Nitrogenous Compounds

List D
Electron Microscope

Asbestos Fibres &
Other Particles

List E
General Chemical

pH
Alkalinity
Hardness
Chlorine
Iron
Turbidity

List F
Carbon Analyser
Dissolved Carbon

List G
Mercury

Mercury by
Flameless Atomic Absorption

List H
Loss on Ignition

H1 %H2O

% Loss on Ignition
H2
Total Carbon

List J
Solvent Extraction

Methylene Chloride Extraction
Infrared Spectrophotometry

MANUFACTURING PROCEDURES FOR WATER TREATMENT CHEMICALS

The manufacturing methods used for the production of most water treatment chemicals are fairly standardized. With alum, however, there exist two different production processes.

A direct method of alum production involves the treatment of bauxite (aluminum ore) with sulphuric acid; the product liquid alum is bluish in colour, due to the presence of reduced iron at about 0.1% and tends to contain high levels of some trace metals. In some alums the colour may be greenish-blue due to the fact that the iron is not completely reduced. Alum produced by this method can be strongly opalescent; the manufacturers ascribe this to the presence of colloidal titanium coming out of solution as the alum cools. This tended to be supported by the analytical results obtained in this study, since the alums with the lowest titanium levels had also low to average turbidities. The opalescence could also be caused by the occasional use of antifoaming agents.

In the other method of alum production, sodium hydroxide is used to dissolve the aluminum from the bauxite; the heat produced during the exothermic reaction aids in the solution of the aluminum. The solution is filtered and allowed to cool, whereupon it becomes supersaturated; careful seeding produces a specific sized hydrate $Al_2 O_3 3H_2O$. This is then treated with sulphuric acid to produce a beige-coloured liquid alum, which tends to contain lower levels of the trace metal contaminants than is found in the "direct" process.

The two processes, described in detail in Appendix 6 result in alums which differ in quality.

RESULTS

STAGE 1. ANALYTICAL RESULTS

The raw data collected during Stage 1, are presented in Appendix 1.

A) PRIMARY COAGULANTS

1. TRACE METALS Aluminum sulphate (liquid) samples were obtained from only two manufacturers; a sample of ferric chloride was also analysed in this stage. The results of trace metal analysis are shown in Appendix 1, A1. As can be seen, metal levels in the two samples of alum were not identical; amounts of cadmium, cobalt, copper, molybdenum, and tin were similar, while sample AN1 had nickel levels about three times those of sample AC1, and zinc levels about seven times higher. Meanwhile, sample AC1 had chromium levels at least one hundred and twenty times those of sample AN1, lead at least five times and manganese a little more than fourteen times higher. Ferric chloride tended to have higher levels of the trace metals than either alum sample, except for chromium and lead (when compared to sample AC1).

2. PHYSICAL PROPERTIES The specific gravities of these three samples of primary coagulants are shown in Appendix 1, A2. The specific gravity of the two alum samples differed only by 0.007; the sample of ferric chloride had a specific gravity of 1.385.

3. ELECTRON MICROSCOPE ANALYSIS The samples of primary coagulants were submitted for electron microscope analysis for asbestos fibres and other particles; due to the nature of the samples, this analysis could not be handled using established techniques and attempts were made to develop a new procedure. No results were obtained in this stage of the program.

STAGE 2. ANALYTICAL RESULTS

The raw data collected in Stage 2 are presented in Appendix 2.

A) PRIMARY COAGULANTS

1. TRACE METALS The results of trace metal analysis on alums and ferric chlorides delivered to six selected water treatment plants are presented in Appendix 2, A1. Few results can be interpreted, most being "less than" figures at fairly high levels, or figures with very wide confidence limits, and the methodology for analysis was termed 'tentative'.

2. PHYSICAL PROPERTIES The specific gravities of these primary coagulants, and other physical properties are shown in Appendix 2, A2. The specific gravity of the alums and the ferric chlorides was fairly uniform, with slightly greater variations being shown in the liquid ferric chlorides. Gravimetric and colorimetric methods for the determination of percent aluminum and percent iron were under development.

3. SOLVENT EXTRACTION/GAS CHROMATOGRAPHY Gas chromatography analysis of methylene chloride extracts of two samples of liquid aluminum sulphate (AC1, AC3) and one of ferric chloride (FC4) showed no detectable dinitrotoluene or related compounds; the detection limit for the method used is 1 to 5 ppb.

4. ELECTRON MICROSCOPE ANALYSIS During this and the previous stage, various methods of preparation were attempted with these materials, but none were successful. This test was therefore abandoned for primary coagulants.

B) RAW AND TREATED WATERS AND WATER PLANT SLUDGES

1. TRACE METALS The results of analysis of raw and treated water at the R.C. Harris water plant for trace metals is shown in Appendix 2, B1; results for the sludge are also shown. The metal present in the highest amount in raw and treated water was magnesium at 7.0 ppm and 6.5 ppm, respectively. Levels of metals in treated water were very low and generally either the same as, or lower than, the levels in the raw water. Levels of metals in the sludge were considerably higher than those found in the waters, with a high of 2400 ppm for aluminum and 2300 ppm for iron, as might be expected from the use of aluminum and/or iron salts for coagulation. Mercury levels in sludge could not be measured because of analytical difficulties.

2. SOLVENT EXTRACTION/GAS CHROMATOGRAPHY As can be seen in Appendix 2, B2, the dinitrotoluenes were not detectable (detection limit 1-5 ppb) in the raw and treated waters and most of the sludges. Only the sludge from the R.L. Clark plant showed low levels of these chemicals, with a result of 0.2 ppm for 2,4-dinitrotoluene, 0.3 ppm for 2,6-dinitrotoluene and 0.04 ppm for trinitrotoluene and related compounds.

C) HYDROFLUOROSILICIC ACID

1. SOLVENT EXTRACTION/GAS CHROMATOGRAPHY Hydrofluorosilicic acid delivered to a number of water plants was analysed by solvent extraction/gas chromatography. Levels of 2,4-dinitrotoluenes were less than 1 and related compounds were non-detectable in all samples (Appendix 2, C1).

STAGE 3. ANALYTICAL RESULTS

The raw water collected in Stage 3 are presented in Appendix 3.

A) PRIMARY COAGULANTS

1. TRACE METALS The results of trace metal analysis on alums delivered to eight selected water treatment plants are shown in Appendix 3, Ala. Again, few results can be interpreted, being similar 'less than' figures at high levels to those in Appendix 2, Al. Similar analysis results for ferric chlorides at two plants are given in Appendix 3, Alb, although mercury analysis by flameless atomic absorption, showed sample FC6 to contain 0.05 ppm.

2. PHYSICAL PROPERTIES Specific gravities of liquid alums and ferric chlorides delivered to water treatment plants during Stage 3 are shown in Appendix 3, A2. Values for the alums vary from a low of 1.31 to a high of 1.335, while variation for the ferric chlorides was a little greater from 1.372 to 1.448. It was too time-consuming to carry out any gravimetric analysis to determine percent aluminum or percent iron, and the application of colorimetric methodology to determine these values was abandoned, because the high dilution factors would introduce an unacceptable experimental error.

3. SOLVENT EXTRACTION/GAS CHROMATOGRAPHY Appendix 3, A3 shows the results obtained by solvent extraction and gas chromatographic analysis of samples of aluminum sulphate from three water treatment plants and samples of ferric chloride from two plants. No 2,4-dinitrotoluene or related compounds were found in any sample.

4. LOSS ON IGNITION, PERCENT MOISTURE AND TOTAL CARBON Eight samples of aluminum sulphate and one of ferric chloride were analysed for loss on ignition, percent moisture and total carbon. The former analyses were difficult to perform because of the difficulty of drying the viscous chemicals. The results are shown in Appendix 3, A4. Total carbon analyses were carried out using a carbon analyser; of the alum samples analysed, values from a low of 8 ppm to a high of 36 ppm total carbon were obtained.

   It had been hoped, by means of these analyses, to develop an identifiable "thumb-print" for each coagulant, which could be related to the manufacturer, but because of the difficulty in analysis, this approach was abandoned.

5. SOLVENT EXTRACTION/INFRARED ANALYSIS AND DISSOLVED ORGANIC CARBON

   The results of dissolved organic carbon analysis (DOC) on appropriate dilutions of the samples are shown in Appendix 3, A5. Methylene chloride extractions were not attempted, because of the low level of DOC found in the samples. Values for DOC of aluminum sulphate samples, varied from a low of 2.1 ppm at R.L. Clark in Toronto to a high of 5 ppm at Sarnia. Grand Bend ferric chloride proved too corrosive to analyse.

B) TREATMENT AIDS

1. TRACE METALS Activated carbon, unslaked lime, the polymer Cat Floc T, sodium bicarbonate and sodium hydroxide were analysed for trace metal content and the results are given in Appendix 3, B1. Numbers were predominantly of the "less than" variety, except for activated carbon, where absolute measurements were obtained for most of the metals when analysis was possible.

Activated carbon contained high amounts of calcium (1800 ppm) and iron (540 ppm), moderate amounts of aluminum (130 ppm), magnesium (100 ppm), and manganese (16 ppm); all other measurable metals occurred at levels less than 8 ppm.

2. LOSS ON IGNITION, PERCENT MOISTURE AND TOTAL CARBON Only activated carbon was analysed for these parameters, with the results being shown in Appendix 3, B2; no result for total carbon was obtained since the carbon analyser was not in service.

3. SOLVENT EXTRACTION/INFRARED ANALYSIS AND DISSOLVED ORGANIC CARBON Activated carbon from the Elgin Area Water System, and sodium bicarbonate from the Port Elgin water plant were extracted with methylene chloride and the extractables were examined by I-R spectrophotometry; the latter material showed traces of extractable substances which could not be identified, because of the broad band which was registered on the spectrogram. No results for DOC analysis were obtained. The tabulated results are shown in Appendix 3, B3.

C) RAW AND TREATED WATERS AND WATER PLANT SLUDGES

1. TRACE METALS The raw and treated waters and water plant sludges (usually a mixture of old, settled sludge and fresh, backwash sludge) were analysed for trace metal content. Samples from a total of six water plants were collected and the results are shown on a plant-by-plant basis in Appendix 3, C1a through Appendix 3, C1f. As can be seen by comparing the available analyses, metal levels in the plant sludges are very much higher than those in either the raw or the treated water, while levels in treated water tend to be very low and equal to or less than those in the raw; this would imply that heavy metals are precipitated out of the water into the sludge on the floc particles.

The method of analysis used for other trace metals (emission spectrophotometry) did not yield acceptable results for mercury. Because of the importance of this parameter to human health, raw and treated waters from seven plants were analysed for this metal by flameless atomic absorption; the results are shown in Appendix 3, C1g. Levels were close to or below detection limits (0.02-0.04 ppb) at all plant locations; the R.L. Clark plant in Toronto had the highest level of 0.05 ppb. No results were obtained for mercury in sludges because of analytical difficulties.

2. SOLVENT EXTRACTION/GAS CHROMATOGRAPHY Water plant sludges from plants at Owen Sound, Sarnia, Goderich, Port Elgin, the Elgin Area System, Grand Bend and Toronto (R.L. Clark) were examined for the presence of 2,4-dinitrotoluene and related compounds. No such materials were detected by gas chromatographic analysis of methylene chloride extracts of the sludges.

3. ELECTRON MICROSCOPE ANALYSIS Raw and treated waters from six selected water plants were examined using the electron microscope for asbestos fibres. No asbestos fibres or other identifiable particulates were detected.

4. GENERAL CHEMISTRY Analysis of routine parameters (pH, hardness, alkalinity, iron, chloride, turbidity, conductivity and dissolved solids) from seven water plants are shown in Appendix 3, C2. Iron and turbidity appear to be the only parameters exhibiting a substantial change between raw and treated water; in six cases, iron concentrations are less in the treated water than in the raw, whereas in Grand Bend (raw 0.12

ppm, treated 1.2 ppm) it is higher in the treated; at this plant ferric chloride is used for coagulation. The turbidity in the treated water was higher than in the raw at both Owen Sound and Grand Bend; in both instances the MOE objective level of 1 FTU was exceeded, with 1.7 FTU at the former and 2.8 FTU at the latter.

5. CARBON ANALYSIS Dissolved organic carbon (DOC) analysis was carried out on raw and treated waters from the same seven plants for which general chemical analyses were performed. The results are shown in Appendix 3, C3, and show that there is little variation in DOC from raw to treated waters or from plant to plant. Values varied from a low of 1.2 ppm in the Port Elgin raw water to a high of 1.8 ppm at Grand Bend, Toronto (R.L. Clark) and the Elgin Area water system raw waters.

6. LOSS ON IGNITION, PERCENT MOISTURE AND TOTAL CARBON. Water plant sludges from five selected plant were analysed for percent moisture, percent loss on ignition and total carbon by carbon analyser. The available results are shown in Appendix 3, C4. The sludges varied in percent moisture quite substantially from a low of 47.7% to a high of 99.2%.

7. SOLVENT EXTRACTION/INFRARED ANALYSIS AND EXTRACTABLE ORGANIC MATERIAL Homogenized samples of water plant sludges from seven plants were air-dried to constant weight, extracted with methylene chloride, and dried again to constant weight. The weight of extracted organics was determined before I-R scans were performed on the extracts. Broad bands on the spectrograms rendered identification of the organic materials impossible. The weight of extracted material varied from a low of 10 ppm (mg per Kg) of dry weight of sludge at Owen Sound to a high of 4000 ppm (mg per Kg) at Sarnia. The results are tabulated in Appendix 3, C5.

D) FLUORIDATION CHEMICALS

1. TRACE METALS. Three samples of hydrofluorosilicic acid and two samples of sodium silicofluoride were analysed for trace metals; because of the corrosivity of the material some of the results must be regarded as semi-quantitive. High levels of arsenic, of about 100 ppm were found in two of the three samples of hydrofluorosilicic acid, while values of less than 100 and less than 120 were reported for the sodium silicofluoride samples. Levels of other toxic metals were low. The results are tabulated in Appendix 3, D1.

2. SOLVENT EXTRACTION/GAS CHROMATOGRAPHY. Thirty six samples of hydrofluorosilicic acid were examined by gas chromatography after methylene chloride extraction, for 2,4-dinitrotoluene and related compounds. The detection limit of the methodology is from 1 to 5 ppb, and all samples showed levels below detection limits.

STAGE 4. ANALYTICAL RESULTS

A) PRIMARY COAGULANTS

1. TRACE METALS. Twenty five samples of liquid aluminum sulphate, four of solid aluminum sulphate and one sample of liquid ferric chloride, delivered to selected water plants, were analysed for trace metal content. During this stage, in an attempt to obtain more accurate results, a majority of the samples were analysed by atomic absorption spectrophotometry. The results are given in Appendix 4, A1a and 4, A1b. The results demonstrate that the "less than" results obtained with the previous analysis were not always a close indication of the actual levels present. There was little overall difference between the solid and liquid alums.

Arsenic levels were not available for most of the samples; lead levels were less than 13 ppm, except for two samples of liquid alum, AN3 and AC13, with levels of 72 ppm and 96 ppm respectively. Most cadmium levels were less than 0.05 ppm, but a high of 0.083 ppm was found in a liquid alum sample (AN3). The liquid ferric chloride was only analysed by emission spectrography and the results were mostly unsatisfactory, being reported as less than 20 ppm for most metals. Mercury levels by flameless atomic absorption analysis were very low with most being less than 0.001 ppm; the highest mercury level was 0.05 ppm in a sample (AN6) of liquid alum.

2. PHYSICAL PROPERTIES The specific gravity, percent free acid, percent free Al_2O_3, colour/turbidity (apparent colour), turbidity and pH, both undiluted and as a one percent solution were determined for twenty five samples of liquid alum; similar analyses, were completed on one sample of ferric chloride and, except for specific gravity, on four samples of liquid alum. Results for the liquid alums are shown in Appendix 4, A2a, and for the other coagulants in Appendix 4, A2b.

The specific gravities of the liquid alums varied from a low of 1.306 to a high of 1.34. Colour/turbidity values varied over a wide range from a low of 25 HU* in two samples to a high of greater than 500 HU in a single sample. This same sample showed a high turbidity reading of 225 FTU**, whereas the lowest turbidity reading was 10 FTU, found in three samples. Four samples of liquid alum showed percentages of free acid ranging from 0.25% to 1.23%; these alums also, as expected, showed the lowest pH in undiluted solutions with values from 0.5 to 1.1. With the exception of the alums with free acid present, the lowest pH in undiluted alum was 1.5, in an alum which showed extremely high turbidity; the highest pH was 2.5. Dilution to a one percent solution resulted in pH values from 3.00, (not in the alum showing the lowest undiluted pH), to 3.87.

The percentage of free Al_2O_3 in the solid alums showed a greater variation than in the liquid samples, with a low of 0.12% and a high of 0.69% compared to 0.01% to 0.38%; the pH's of one percent solutions of solid alums were equivalent to those obtained with liquid alums.

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* HU = Hazen units ** FTU = formazin turbidity units.

The one percent solution of liquid ferric chloride, at pH 2.09, possessed the lowest pH of all samples of primary coagulants tested at the 1% solution level.

3. SOLVENT EXTRACTION/GAS CHROMATOGRAPHY. Six samples of liquid aluminum sulphate and one of solid were analysed by gas chromatography after extraction with methylene chloride. Only one sample (AC17) of liquid alum showed 0.03 ppm of 2,4-dinitrotoluene; all other samples, as shown in Appendix 4, A3, contained non-detectable levels of this compound, 2,6-dinitrotoluene and related compounds.

4. LOSS ON IGNITION, PERCENT MOISTURE AND TOTAL CARBON. Twenty samples of liquid alum were examined for percent moisture at 105°C and percent loss on ignition. Percent moisture varied from a low value of 58% to a high of 64%. The minimum value for loss on ignition was 8.9% with most values being over 11% with a high of 12.6% (Appendix 4, A4a).

Only one sample of sodium aluminate was analysed; the percent moisture at 105°C was 50% with percent loss on ignition being considerably lower than the corresponding value in liquid aluminum sulphate, at 2.4%.

The four samples of solid aluminum sulphate had percent moisture values from 21% to 30%, with percent loss on ignition varying from 14.0% to 19%.

Liquid ferric chloride samples possessed a percent moisture content similar to liquid alum from 61% to 70%, but percentage loss on ignition values were slightly lower, being 7.4% to 11%. Total carbon analysis was not carried out. Results for these coagulants are tabulated in Appendix 4, A4b.

5. SOLVENT EXTRACTION/INFRARED ANALYSIS AND DISSOLVED ORGANIC CARBON.

Three samples of aluminum sulphate, from plants at Lindsay, Kenora and Toronto (R.C. Harris) were examined. Direct DOC analysis of the coagulants at an appropriate dilution yielded levels of 2.9, 1.8 and 2.7 ppm respectively. Methylene chloride extraction was not attempted, due to the low levels of DOC. The ferric chloride from the Easterly water plant in Scarborough proved too corrosive for analysis. These results are shown in Appendix 4, A5.

B) TREATMENT AIDS

1. TRACE METALS. Samples of unslaked lime, soda ash and a single sample of sodium bicarbonate were analysed for trace metals, the majority by atomic absorption spectrophotometry. The results are tabulated in Appendix 4, B1. No results were obtained for arsenic; cadmium results showed levels of less than 0.05 in the soda ash and sodium bicarbonate, while the three samples of unslaked lime showed levels of 1.6 ppm, 0.26 ppm and 0.14 ppm. Lead levels were less than 0.6 ppm with the exception of one sample of unslaked lime with a reading of 2.9. Although emission spectrography gave a result of less than 400 ppm mercury in one sample of unslaked lime (LU2), accurate (flameless atomic absorption spectrophotometry) mercury results showed levels of less than 0.01 ppm in the remaining treatment aids.

2. LOSS ON IGNITION, PERCENT MOISTURE AND TOTAL CARBON. No analysis for these parameters was available.

3. SOLVENT EXTRACTION/INFRARED ANALYSIS AND DISSOLVED ORGANIC CARBON.

Only unslaked lime from the R.C. Harris plant in Toronto was tested. Although no value for DOC was obtained, the I-R scan of the methylene chloride extract revealed the presence of organic material which could not be identified because of the broad band occurring in the spectrogram (Appendix 4, B2).

C) RAW AND TREATED WATERS AND WATER PLANT SLUDGES.

1. TRACE METALS. The raw and treated waters and water plant sludges from eight water plants were analysed for trace metal content by emission spectrophotometry; the results are shown in Appendix 4, C1a through 4, C1h. Levels of trace metals in the raw water were low, with similar or lower levels appearing in the treated water. Levels of most metals, for which results were available were very much higher in the sludges than in either the raw or treated waters, as was revealed by the analysis in Stage 3 (Appendix 3,, C1a through Appendix 3, C1f). Mercury was analysed by flameless atomic absorption, rather than by emission spectrophotometry, in raw and treated waters, and the results are shown in Appendix 4, C1i. Half of the samples failed to yield results because of problems experienced with the analytical method; results from the other samples show mercury levels less than 0.08 ppb. No results for mercury analysis were obtained for the water plant sludges.

2. GENERAL CHEMISTRY. Results of analyses for general chemical parameters in the raw and treated waters from eight treatment plants are given in Appendix 4, C2. Iron levels were consistently lower in the treated as compared to the raw water. In three cases (Arnprior, Lindsay and Toronto (R.C. Harris) the turbidity in the finished water exceeded the MOE objective level of 1 NTU; in the case of Arnprior, turbidity in the treated water was more than double that in the raw. However, these turbidities were analysed at the laboratory and not at the plants, and turbidities can be affected by transit time.

3. CARBON ANALYSIS. Appendix 4, C3 tabulates the results of the analyses of raw and treated waters for dissolved organic carbon (DOC). At these plants there was a general trend for DOC values to be lower in the treated waters than in the raw. The raw water level was highest at Kenora (8.8 ppm) and lowest at Cornwall (2.0 ppm). The highest treated water level was detected at Lindsay (7.5 ppm), where treatment apparently had little effect in reducing DOC, and lowest at Cornwall (1.9 ppm) although this was also close to the raw water level of 2.0 ppm.

4. LOSS ON IGNITION, PERCENT MOISTURE AND TOTAL CARBON. Backwash sludges from four water plants were analysed for percent moisture at 105°C, loss on ignition and total carbon by the carbon analyser. Appendix 4, C4 shows that there was little variation in percent moisture in the three samples where results were obtained. Percent loss on ignition, however varied from a low of 0.045% at Lindsay to a high of 1.3% at Toronto (R.C. Harris). This latter location also showed the highest level of total carbon at 5900 ppm, compared to 2300 ppm at Lindsay and 490 ppm at Kenora.

5. SOLVENT EXTRACTION/INFRARED ANALYSIS AND EXTRACTABLE ORGANIC MATERIAL

Methylene chloride extracts of dried water plant sludges from four plants were examined by infrared spectrophotometry; the results are shown in Appendix 4, C5. As with the sludges examined in Stage 3, organics detected by infrared scans could not be identified. The extractable organics measured varied widely, from a low of 4 ppm (mg per Kg dried weight) at Kenora to a high of 11000 ppm at Scarborough (Easterly).

D) FLUORIDATION CHEMICALS

1. SOLVENT EXTRACTION/GAS CHROMATOGRAPHY. Sixty-three samples of hydrofluorosilicic acid were analysed by gas chromatography for the presence of 2,4-dinitrotoluene and related compounds after methylene chloride extraction. The results, shown in Appendix 4, D1, show that low levels of 2,4-dinitrotoluene were detectable in some samples, to a maximum of 2.1 ppm, whereas 2,6-dinitrotoluene and related compounds could not be detected.

DISCUSSION

To assess the effects of the various contaminants in treatment chemicals on the treatment process and the quality of the finished water, it is useful to discuss selected results obtained from all four stages of the study. In this way, a total picture of quality variation in treatment chemicals with respect to contamination levels can be obtained.

TRACE METAL CONTAMINATION

Table 5 shows the recommended limits or maximum acceptable concentration (MAC) for trace metals, in the Ontario Drinking Water Objectives (2). Further, the table shows the concentration of metal that would have to be present in the treatment chemicals, to result in the MAC appearing in the finished drinking water, at dosages of 50 ppm, 25 ppm or 5 ppm of the chemical, assuming no input from other sources. For example, for a chemical used at a dose of 50 ppm, 1000 ppm of arsenic would have to be present in that chemical to produce the MAC in the finished water; when used at a dose of 25 ppm, then 2000 ppm of contaminating arsenic would be required to produce the MAC and at a dose of 5 ppm the required arsenic levels would be 10,000 ppm.

There was a good deal of interference with the analytical techniques due to the nature of some of the materials which were analysed in this study. The semi-quantitative nature of some results rendered interpretation very difficult. In the following discussion both the highest definitive result obtained and the highest determined levels (usually a "less than" number) have been incorporated; it should be realized that the former are the more accurate, with the latter semi-quantitative results representing a 'worst case' situation.

TABLE 5. RECOMMENDED LIMITS FOR METALS IN DRINKING WATER AND CONTAMINATION LEVELS REQUIRED IN TREATMENT PLANT CHEMICALS TO REACH THOSE LIMITS, AT THREE SPECIFIED DOSAGES, ASSUMING NO INPUT FROM OTHER SOURCES.

Metal	Recommended Limits MAC*(mg/L)	Concentrations of contaminant in treatment chemical that is required to produce the MAC at the following dosages 50 ppm	25 ppm	5 ppm
Arsenic	0.05	1,000	2,000	10,000
Barium	1.0	20,000	40,000	200,000
Boron	5.0	100,000	200,000	1,000,000
Cadmium	0.005	100	200	1,000
Lead	0.05	1,000	2,000	10,000
Mercury	0.001	20	40	200
Selenium	0.01	200	400	2,000
Silver	0.05	1,000	2,000	10,000
Uranium[1]	0.02	400	800	4,000
Chromium	0.05	1,000	2,000	10,000

*MAC = maximum acceptable concentration, Ontario Drinking Water Objectives (MOE, 1983)

[1] = Interim MAC

In primary coagulants supplied directly from the manufacturer, only chromium appeared at high levels, with 50 ppm in one alum sample and 15 ppm in a sample of ferric chloride. Lead appeared at 3.3 ppm in an alum sample and manganese at 7.8 ppm in the same sample (Appendix 1. A1.)

Some typical results of metal analysis in alum and ferric chloride supplied by various manufacturers are shown in Table 6. As can be seen, one sample of liquid alum (liquid alum 3) showed chromium, iron, manganese, lead, titanium and vanadium considerably higher than in liquid alum(1); liquid alum (2) had higher cadmium and chromium levels; a sample of solid alum (1), displayed similar levels. This is due to differences in the manufacturing procedure, as explained under "Manufacturing Procedures" and in Appendix 6.

Table 7 shows some selected analyses obtained from single samples of various treatment aids and Table 8 from samples of fluoridation chemicals; highest levels for iron were recorded in unslaked lime, the polymer Cat Floc T and in activated carbon. The highest definitive level of arsenic (97 ppm) was recorded for a sample of hydrofluorosilicic acid (1), although most of the analyses for the treatment aids were of the "less than" variety, at about 100 ppm. Levels of other metals in fluoridation chemicals were low.

The highest levels recorded for the four most toxic trace metals - arsenic, cadmium, lead and mercury have been charted. On Chart 1 are plotted the figures from the 50 ppm dosage columns in Table 5, for these metals, in addition to the highest concentrations of them recorded in primary coagulants also assuming a 50 ppm dose rate. Since primary coagulants are normally applied at 1 to 10 ppm this dosage rate is an uncommonly high one and was chosen to present the worst possible case. The highest level of arsenic found in a primary coagulant was 0.08 ppm in a sample of liquid alum, with a level of less than 300 ppm in a

TABLE 6. TYPICAL SELECTED TRACE METAL RESULTS OF PRIMARY COAGULANTS (APPENDICES 2 and 4)

			COAGULANT			
Trace Metal (ppm) as metal	Liquid Alum(1)	Liquid Alum(2)	Liquid Alum(3)	Solid Alum(1)	Solid Alum(2)	Ferric Chloride
Antimony	-#	-	<20	-	-	<30
Arsenic	-	-	0.08	-	-	<300
Beryllium	<0.03	-	<2	<0.03	<0.03	<10
Cadmium	<0.05	0.67	0.03	<0.05	<0.05	<10
Chromium	1.8	50.0	41.0	75.0	0.41	10
Cobalt	<0.5	0.52	<0.2	<0.5	<0.5	10-30
Copper	2.14	0.67	<0.05	1.8	1.7	10-30
Iron	2.91	-	>2000	1530	0.82	-
Lead	0.88	0.25	96.0	13.1	<0.6	<10
Manganese	3.25	-	60-120	12.7	3.8	-
Mercury	0.05	-	<200	<0.01	0.03	0.05
Nickel	1.5	1.3	0.35	<0.5	1.0	10-30
Strontium	0.28	-	<60	2.4	0.18	<100
Tin	-	-	<20	-	-	<30
Titanium	2.15	-	600-2000	136	3.08	-
Vanadium	2.85	-	10-30	38.2	3.86	10-30
Zinc	1.6	2.6	<0.25	3.5	0.25	-

# result not available

TABLE 7. TYPICAL SELECTED TRACE METAL RESULTS OF VAROUS TREATMENT AIDS (APPENDICES 3 and 4)

Treatment Aid Trace Metal (ppm) as metal	Activated Carbon	Unslaked Lime	Polymer Cat-Floc T	Sodium Bicarbonate	Sodium Hydroxide
Antimony	-#	<40	<400	-	<50
Arsenic	<0.2	<120	<120	-	<100
Beryllium	<0.5	-	<12	<0.6	<0.5
Cadmium	0.1	1.6	<12	<0.05	<10
Chromium	2.5	23.0	<12	0.12	tr-<0.5
Cobalt	-	<1.0	-	<0.5	<1.0
Copper	0.9	12.0	∿12	<0.6	0.5-1.0
Iron	540.0	4000	1200-4000	<0.36	10-20
Lead	<0.4	2.9	∿40	<0.6	<10
Manganese	16.0	40-120	tr-<12	<0.6	tr-0.5
Mercury	-	<400	<400	<0.01	-
Nickel	3.1	2.6	tr-<12	<0.5	<3
Strontium	2.4	400-1200	<120	2.05	3-10
Tin	-	<40	<12	-	<10
Titanium	8.0	12-40	<12	<1.25	<0.5
Vanadium	<2.0	tr-<12.0	<12	<1.25	-
Zinc	0.78	9.3	-	0.88	<10

# result not available

TABLE 8. TYPICAL SELECTED TRACE METAL RESULTS OF FLUORIDATION CHEMICALS (APPENDIX 3)

Chemical Trace Metal (ppm) as metal	Hydrofluorosilicic Acid		Sodium Silicofluoride
	1	2	
Antimony	-#	<0.27	<40
Arsenic	97.0	∿0.8	<120
Beryllium	-	<0.27	<12
Cadmium	0.02	<0.27	<12
Chromium	0.34	∿0.27	tr-<40
Cobalt	-	-	-
Copper	1.4	∿2.7	tr-<12
Iron	24	<27	∿40
Lead	0.09	tr-<0.27	<12
Manganese	0.64	0.27-80	40-120
Mercury	-	<0.8	<400
Nickel	1.1	0.8-2.7	tr-<12
Strontium	-	0.27-0.8	<12
Tin	-	<0.27	<40
Titanium	-	8.27	tr-<12
Vanadium	-	∿0.27	<12
Zinc	0.4	-	-

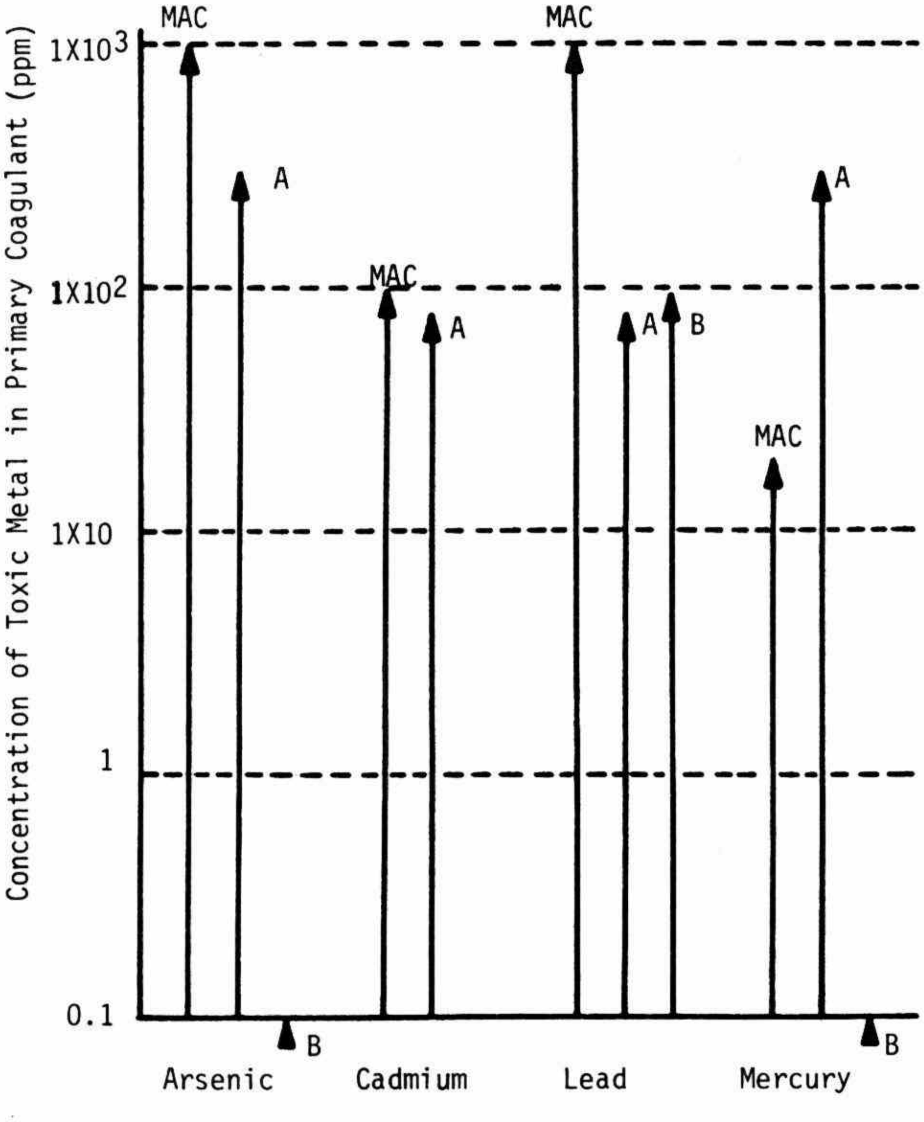
result not available

sample of ferric chloride; cadmium appeared at the highest level in ferric chloride at less than 80 ppm and at 0.67 ppm in a sample of liquid aluminum sulphate; most levels determined by atomic absorption were less than 0.05 ppm. A sample of alum was found to contain 96 ppm of lead, the highest level recorded. Although some measurements of mercury were less than 300 ppm in liquid alum and less than 240 ppm in ferric chloride, determination by flameless atomic absorption revealed a maximum level of 0.05 ppm in a sample of liquid alum and a sample of ferric chloride (Chart 1).

In the case of treatment aids, a similar plot is shown in Chart 2, but assuming a dose rate of 25 ppm which is considerably higher than that normally used. Arsenic appeared at a level of less than 120 ppm in Cat Floc T and unslaked lime; cadmium was detected at the less than 12 ppm level in Cat Floc T and in unslaked lime, with a definitive level of 1.6 ppm in unslaked lime. For lead, the corresponding figures were about 40 ppm for the polymer Cat Floc T and 2.9 ppm in unslaked lime; for mercury the highest level recorded was less than 400 ppm in Cat Floc T and unslaked lime although determination by atomic absorption showed levels of less than 0.01 ppm. These results are charted in Chart 2.

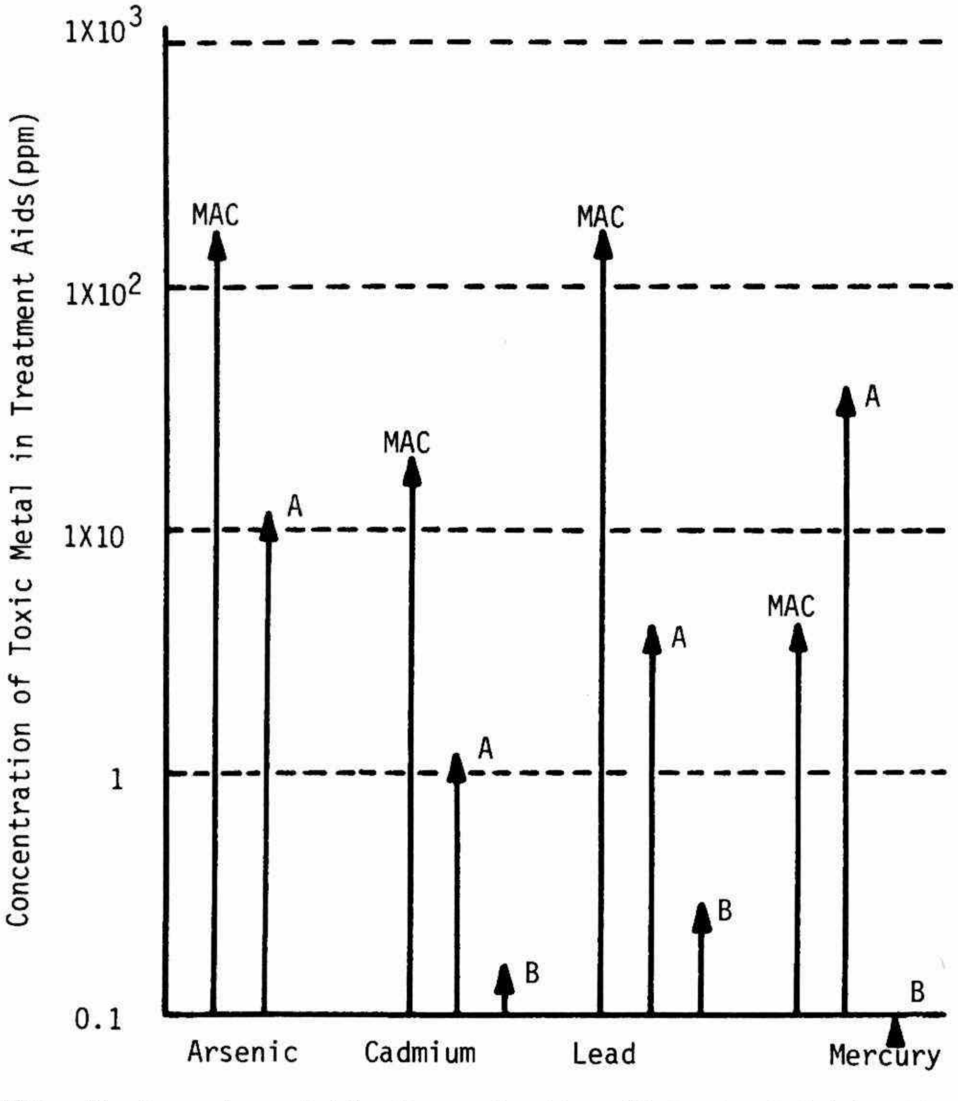
For fluoridation chemicals, a dosage rate of 5 ppm was chosen; they are normally dosed at approximately this level (5.5 ppm, to yield a 1 ppm fluoride residual). The highest levels of arsenic in such chemicals was less than 120 ppm in a sample of sodium silicofluoride and 97 ppm in a sample of fluosilicic acid. Cadmium was found at less than 12 ppm in sodium silicofluoride, and 0.02 ppm in hydrofluorosilicic acid. Equivalent figures for lead were less than 12 ppm in sodium silicofluoride and 1.5 ppm in fluosilicic acid, and for mercury less than 400 ppm in sodium silicofluoride. These results are shown in Chart 3.

CHART 1. COMPARISON OF THE HIGHEST LEVELS OF FOUR TOXIC METALS (ARSENIC, CADMIUM, LEAD and MERCURY) REPORTED IN PRIMARY COAGULANTS, WITH THE LEVELS REQUIRED TO PRODUCE THE MAC* IN THE FINISHED WATER, ASSUMING A DOSE OF 50ppm.



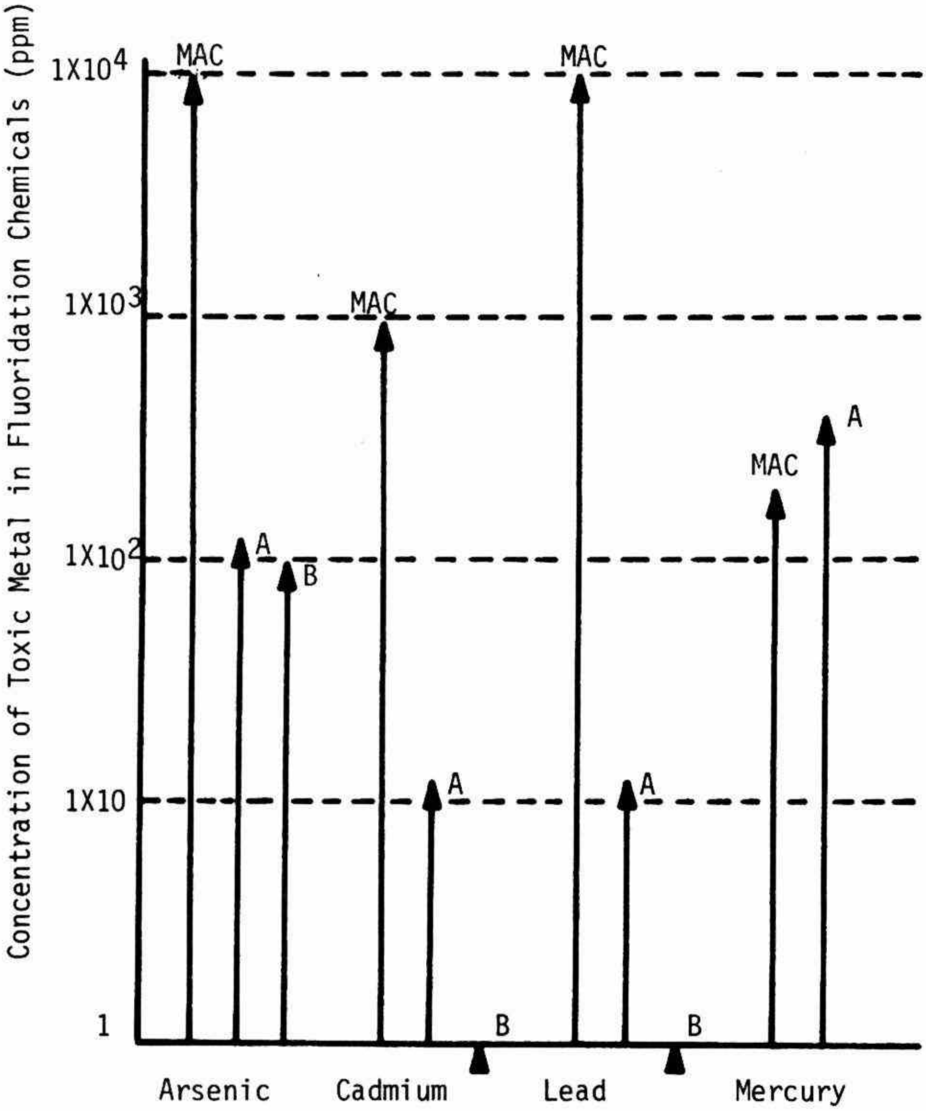
* MAC - Maximum Acceptable Concentration (Ontario Drinking Water Objectives)
A - High Level (semi-quantitative result)
B - High Definitive Level

CHART 2. COMPARISON OF THE HIGHEST LEVELS OF FOUR TOXIC METALS (ARSENIC, CADMIUM, LEAD and MERCURY) REPORTED IN TREATMENT AIDS, WITH THE LEVELS REQUIRED TO PRODUCE THE MAC* IN THE FINISHED WATER, ASSUMING A DOSE OF 25ppm.



* MAC - Maximum Acceptable Concentration (Ontario Drinking Water Objectives)
A - High Level(semi-quantitative result)
B - High Definitive Level

CHART 3. COMPARISON OF THE HIGHEST LEVELS OF FOUR TOXIC METALS (ARSENIC, CADMIUM, LEAD and MERCURY) REPORTED IN FLUORIDATION CHEMICALS, WITH THE LEVELS REQUIRED TO PRODUCE THE MAC* IN THE FINISHED WATER, ASSUMING A DOSE OF 5ppm.



* MAC - Maximum Acceptable Concentration (Ontario Drinking Water Objectives)
A - High Level (semi-quantitative result)
B - High Definitive Level

From the charts (Chart 1 through 3) it can be seen that the amounts of the most toxic trace metals found contaminating a range of water treatment chemicals are significantly below those required to produce levels in the finished water which would cause concern for health even if used at abnormally high dose rates.

Tables 9a, 9b, 9c, and 9d present results of analyses of coagulant chemicals, raw and treated water and water plant sludges from selected water treatment plants in Ontario, for arsenic, cadmium, lead and mercury. As can be seen, levels of these metals in raw and treated waters were low, with a maximum of <0.05 ppm for arsenic, <0.01 ppm for cadmium, <0.05 for lead and <0.00008 ppm for mercury in treated water. The sludges generally showed metal levels at least eight to ten times those in the raw or treated waters for arsenic and at least nineteen times for cadmium; the lead levels were about 10 times as great. Sludge could not be analyzed for mercury. These results would indicate that arsenic, cadmium and lead, either present in the raw water or added during the treatment process in the treatment chemicals, are precipitated during sedimentation into the sludge. Analyses results for other metals in waters and sludges show a similar trend.

PHYSICAL PROPERTIES

The physical characteristics of the primary coagulant, alum, varied from manufacturer to manufacturer, and even from batch to batch, sometimes by a very wide margin. The variation in quality probably resulted from differences in the manufacturing processes. The variations were great enough that the use of a different alum could cause changes in coagulating and flocculating conditions and necessitate modifications in the feed rate of the chemical.

TABLE 9a. ARSENIC LEVELS IN COAGULANTS, RAW AND TREATED WATER AND WATER PLANT SLUDGES FROM SELECTED WATER TREATMENT PLANTS IN ONTARIO

Location	Coagulant	Arsenic in			
		Coagulant (ppm)	Raw Water (ppm)	Treated Water (ppm)	Sludge (ppm)
Toronto (R.C. Harris)	Alum	<20	<0.05	<0.05	0.88
Toronto (R.L. Clark)	Alum	<20	<0.05	<0.05	0.73
Lindsay	Alum	<20	<0.05	<0.05	0.32
Kenora	Alum	<20	<0.05	<0.05	0.37
Owen Sound	Alum	<30	<0.0025	<0.0025	0.26
Goderich	Alum	<30	<0.004	<0.0025	Int*
Sarnia	Alum	<30	<0.0025	<0.0025	Int*
Grand Bend	Ferric Chloride	<300	<0.003	<0.0026	Int*.

*Int = interference with analytical method

TABLE 9b. CADMIUM LEVELS IN COAGULANTS, RAW AND TREATED WATER AND WATER PLANT SLUDGES FROM SELECTED WATER TREATMENT PLANTS IN ONTARIO

Location	Coagulant	Cadmium in			
		Coagulant (ppm)	Raw Water (ppm)	Treated Water (ppm)	Sludge (ppm)
Toronto (R.C. Harris)	Alum	<20	<0.01	<0.01	0.19
Toronto (R.L. Clark)	Alum	<20	<0.01	<0.01	<0.02
Lindsay	Alum	<20	<0.01	<0.01	<0.02
Kenora	Alum	<20	<0.01	<0.01	<0.02
Owen Sound	Alum	<10	<0.0005	<0.0005	0.51
Goderich	Alum	<10	<0.0005	<0.0005	<0.02
Sarnia	Alum	<10	<0.0005	<0.0005	0.1
Grand Bend	Ferric Chloride	<10	0.0005	0.0005	0.6

TABLE 9c. LEAD LEVELS IN COAGULANTS, RAW AND TREATED WATER AND WATER PLANT SLUDGES FROM SELECTED WATER TREATMENT PLANTS IN ONTARIO

Location	Coagulant	Lead in Coagulant (ppm)	Raw Water (ppm)	Treated Water (ppm)	Sludge (ppm)
Toronto (R.C. Harris)	Alum	<10	<0.05	<0.05	<0.4
Toronto (R.L. Clark)	Alum	<20	<0.05	<0.05	1.4
Lindsay	Alum	<20	<0.05	<0.05	<0.4
Kenora	Alum	<20	<0.05	<0.05	<0.4
Owen Sound	Alum	<10	0.004	0.007	<0.4
Goderich	Alum	<10	0.0095	0.006	5.6
Sarnia	Alum	<10	<0.0025	<0.0025	<0.4
Grand Bend	Ferric Chloride	<10	0.007	<0.009	14.7

TABLE 9d. MERCURY LEVELS IN COAGULANTS, RAW AND TREATED WATER AND WATER PLANT SLUDGES FROM SELECTED WATER TREATMENT PLANTS IN ONTARIO

Location	Coagulant	Mercury in Coagulant (ppm)	Raw Water (ppm)	Treated Water (ppm)	Sludge (ppm)
Toronto (R.C. Harris)	Alum	<200	<0.00008	<0.00008	-#
Toronto (R.L. Clark)	Alum	<200	0.00005	0.00005	-
Lindsay	Alum	<200	<0.00003	<0.00003	-
Kenora	Alum	<200	0.00005	0.00007	-
Owen Sound	Alum	<100	<0.00003	<0.00003	-
Goderich	Alum	<100	<0.00004	<0.00004	-
Sarnia	Alum	<100	<0.00004	<0.00004	-
Grand Bend	Ferric Chloride	<300	<0.00004	<0.00004	-

# result not available

TABLE 10. PHYSICAL CHARACTERISTICS OF SELECTED LIQUID ALUMS DELIVERED TO SELECTED WATER TREATMENT PLANTS

Location of Liquid Alums	Undiluted pH	Spec. Gravity* @ 20°C	Colour/Turbidity Hazen Units	Turbidity FTU	% Free Acid	% Free Alumina
Emo (1)	1.10	1.329	25 clear beige	10	0.25	--
Kenora New (2)	0.80	1.306	25 clear beige	10	0.85	--
Kenora Old (3)	0.61	1.326	40 clear beige	20	1.19	--
Kenora (4)	0.5	1.325	50 clear beige	20	1.23	--
Rainy River (5)	2.18	1.320	50 clear beige	10	--	0.08
Kingston (6)	2.50	1.325	50 clear beige	20	--	0.28
Deseronto (7)	2.25	1.339	210 green/blue, opal^{+}.	55	--	0.13
Thorold (8)	2.20	1.334	220 green/blue, clear	70	--	0.09
Niagara Falls (9)	2.15	1.332	290 green/blue, turbid	70	--	0.07
Port Elgin (10)	1.50	1.333	>500 green/blue,very turbid	225	--	0.01
Deseronto (11)	2.25	1.328	290 green/blue, turbid	65	--	0.17
Hawkesbury (12)	2.15	1.330	140 green/blue, opal.	50	--	0.13

* Specific gravity
+ opalescent

Table 10 shows the physical characteristics of various samples of liquid alums; these twelve alum samples were chosen for inclusion in the table because they best represent the differences in quality in liquid alums from all three of the manufacturers.

The pH of the alums varied from a minimum of 0.50 for the number (2) alum that was delivered to Kenora, to a maximum of 2.5 for the number (6) alum that was delivered to Kingston. The percentage of free Al_2O_3 or free acid, directly affects the pH of liquid alum; these two parameters are incompatible and will not be found co-existing in a sample of alum, because of the basic nature of Al_2O_3. The highest percentage of free acid shown in Table 10, is 1.23% in the number (4) alum having the lowest pH; 0.28% free Al_2O_3 occurred in the number (6) alum delivered to Kingston, the sample showing the highest pH.

Because the presence of turbidity affects the measurement of colour, the turbidity of a sample must be considered when colour is measured. Colour, however, does not significantly affect the turbidity measurement when measured on Hach DR2 spectrophotometer; this instrument was chosen for the analysis because it is the instrument most commonly found in water plants, thus making the analysis of these two parameters feasible in a large number of water plants. The variation in the colour/turbidity parameter between the liquid alums (Table 10) was large; the lowest reading obtained was 25 Hazen units for the alums (numbers (1) and (2)) supplied to Kenora and Emo, while the highest reading of greater than 500 Hazen units was found in the number (10) alum shipped to Port Elgin.

Some alums were clear liquids of light beige colour. Other alums (numbers (7) through (12)) were a variable greenish-blue in colour and had an opalescence that varied from slight to very heavy; this factor led to high readings for both colour/turbidity and turbidity. The average colour/turbidity reading for alums (1) through (5) was 38 Hazen units with a range from 25 to 50. Colour/turbidity readings for alums (7) through (12) ranged from 120 Hazen units to a high of greater than 500 Hazen units; the average reading of the samples giving a definite measurement was 194.4 Hazen units; they are produced from bauxite using the direct process.

The range of turbidity measurements varied from 10 FTU on three samples of alum (1)(2) and (4) to 225 FTU on the alum number (10) delivered to Port Elgin; this latter alum was of poor quality and should not have been accepted for water treatment purposes.

The most important physical parameter examined is the specific gravity, since it indicates the strength of the liquid alums. Specific gravities varied from 1.306 for alum number (2) at Kenora, to 1.339 for the alum number (7) delivered to Deseronto.

A specific gravity of 1.335 yields the rated 48.5% w/w concentration that is quoted in manufacturers' specifications.

The results of trace metal, percent Al_2O_3 and pH of 1% solution analyses for the solid alums are shown in Table 11. Minor differences in the percent of free Al_2O_3 and the pH of one percent solutions (w/w) were observed, but these were not significant enough to affect their efficiency. Differences in calcium, iron, chromium, lead, titanium and vanadium levels were demonstrated.

SOLVENT EXTRACTION/GAS CHROMATOGRAPHY

Gas chromatography of methylene chloride extracts of primary coagulants showed an absence of dinitrotoluene and associated nitrogenous compounds, and these compounds were not detected in any of the raw or treated water plant samples that were examined. Some samples of hydrofluorosilicic acid had measurable levels of 2,4-dinitrotoluene present, the highest being 2.4 ppm, but the associated compounds were below detection limits; 2,4-dinitrotoluene and the other nitrogenous compounds were extracted from one sample of water plant sludge from the R.L. Clark water plant in Toronto (Appendix 2, C2) at levels below 0.5 ppm. Water plant chemicals are unlikely to be a source of these organic compounds in the finished water.

TABLE 11. SELECTED TRACE METALS AND PHYSICAL CHARACTERISTICS OF SELECTED SOLID ALUMS DELIVERED TO WATER TREATMENT PLANTS

	Solid Aluminum Sulphate			
Parameter/Material	AC 14	AN 4	AN 5	AC 15
Calcium (ppm as metal)	74	5.4	8.9	103
Chromium " " "	75	0.41	0.47	72
Iron " " "	1530	0.82	42.3	1100.0
Lead " " "	13.1	<0.6	<0.6	17.8
Titanium " " "	136	3.08	3.77	52.8
Vanadium " " "	38.2	3.86	4.05	31.3
Percent Free Al_2O_3	0.12	0.47	0.69	0.31
pH of 1% solution	3.48	3.55	3.76	3.52

ELECTRON MICROSCOPE ANALYSIS

Analysis by the electron microscope for asbestos and other particulates proved unsuccessful for the treatment chemicals. However, since no asbestos or other identifiable particulates were detected in the raw or treated waters it is unlikely that the chemicals could be a significant source of such material in drinking water.

INFRARED ANALYSIS, DISSOLVED ORGANIC CARBON AND EXTRACTABLE ORGANIC MATERIAL

DOC analysis of suitable aqueous dilutions of treatment chemicals revealed low levels. The highest DOC was recorded in the alum from Sarnia at 5 ppm, and the lowest of 1.8 ppm in the alum from Kenora. Methylene chloride extraction was not attempted because of these low DOC levels; such an extraction would have yielded too little extractable material for I-R analysis.

In the case of the treatment aids analysed, only unslaked lime, and sodium bicarbonate showed some unidentifiable organics upon infrared analysis; no results were obtained for DOC determinations.

Extractable organic material was found in dried samples of water plant sludges; levels ranged from a low of 4 ppm (mg/Kg dried weight of sludge) at Kenora to a high of 11,000 ppm at Scarborough's Easterly plant. It is interesting that increasing levels of extractable organics were registered in the sludges in progressing from Owen Sound (10 ppm) to Goderich (33 ppm), Grand Bend (360 ppm) and Sarnia (4000 ppm) in a southward direction along the Lake Huron shoreline. A similar trend in levels occurred in moving into Lake Erie with the Elgin area system at 790 ppm and then Lake Ontario's R.C. Harris plant at 1780 ppm and Easterly at 11,000 ppm. Lindsay, a plant in an industrialized area, produced a sludge with a DOC of 3500 ppm, whilst the Kenora plant (non-industrialized) had a level of 4.0 ppm.

All the dried methylene chloride extracts showed the presence of organics upon analysis by infrared, but no identification was possible.

These results are tabulated in Table 12, and indicate that water treatment plant chemicals do contain organic material; the exact amounts and identities of the materials could not be determined. Given the dosages at which treatment chemicals are used, treatment plant chemicals would not be expected to contribute greatly to the organic content of the finished water. The results of recent surveys* of drinking waters, indicate that the contribution of organic substances to the finished drinking from contamination of treatment chemicals is insignificant. Most of the organic contaminants detected could be found in the raw water, or were known to be generated by reaction between treatment chemicals and organic substances present in the raw water.

(* 1. Trace Organics in Ontario Drinking Water along the Niagara River. Canada-Ontario Agreement, Board of Review 1985

2. Drinking Water Survey of Selected Municipalities in the Niagara Area and Lake Ontario, Ontario Ministry of the Environment, November, 1984)

TABLE 12. DISSOLVED ORGANIC CARBON OF ALUMS AND INFRARED ANALYSIS AND EXTRACTABLE ORGANIC MATERIAL IN METHYLENE CHLORIDE EXTRACTS OF SELECTED WATER PLANT SLUDGES

	Alum		Water Plant Sludge	
Water Plant	DOC(ppm)*	I-R	Extractable Material (ppm)**	I-R
Owen Sound	3.7	NA[1]	10	+[2]
Goderich	4.2	NA	33	+
Grand Bend	***		360	+
Sarnia	5.0	NA	4000	+
Elgin Area W.S.	3.7	NA	790	+
Toronto (R.C. Harris)	2.7	NA	1780	+
Scarborough (Easterly)	***		11000	+
Lindsay	2.9	NA	3500	+
Kenora	1.8	NA	4	+
Toronto (R.L. Clark)	2.1	NA	NA	+
Port Elgin	3.5	NA	NA	+

*DOC-ppm; analysis of suitable aqueous dilution

**extractable material, mg/Kg of dried weight of sludge

***ferric chloride used as coagulant

[1] extraction not attempted, because DOC levels were low

[2] organics detected by I-R, but not identifiable because of broad-banding in the spectrograph

FURTHER INVESTIGATIONS

A) POTENTIAL TREATMENT PROBLEMS CAUSED BY QUALITY VARIATIONS IN TREATMENT CHEMICALS

Most water treatment chemicals demonstrated constant quality. The characteristics of lime and alum, however, varied from manufacturer to manufacturer and even from batch to batch, sometimes by a very wide margin.

Variations in the quality of lime and alum, because of the amounts used in water treatment, would be the most likely to result in problems in the treatment process. An investigation was carried out to determine how such variations might affect the efficiency and operation of the treatment process.

As well as variations in the quality of chemicals delivered to the plants, quality change occurred as a result of storage and handling practices at the water plants.

The quality of lime was often deteriorated because of improper and/or prolonged storage at the water plant. Open bin or open bag conditions allowed moisture and carbon dioxide to produce a build-up of insoluble calcium carbonate; this often reduced the potency to a point where it became quite ineffective for its intended purpose. Lime containing a high percentage of calcium carbonate should neither be used nor accepted at a water treatment plant.

Handling of the material can also cause problems. Cases were observed where slaked lime solution was mixed by aeration; this again would result in calcium carbonate build-up in the solution and render the chemical virtually useless in the treatment process.

Some large differences were found in the pH of both diluted and undiluted alums. As shown in Table 13, the pH of one percent solutions of liquid alum varied from a low of 2.7 (liquid alum (F)), to a maximum of 3.58 (liquid alum (D)). Water with a moderate

TABLE 13. pH of 1% SOLUTIONS OF VARIOUS ALUMS AND REDUCTION OF pH AND ALKALINITY CAUSED BY THEIR ADDITION TO RAW WATERS OF DIFFERING ALKALINITY

Solid or Liquid Alum	pH of 1% of w/v soln.	Alkalinity Reduction per ppm Alum	Initial Reduction of pH	Reduction of pH after 15 min.	Type of Water & Alum Dosage
Solid Alum (A)	3.48	0.45	0.78	0.30	100 ppm alk.* 40 ppm alum
Solid Alum (B)	3.55	0.45	0.75	0.30	100 ppm alk. 40 ppm alum
Liquid Alum (C)	2.85	0.50	0.85	0.40	100 ppm alk. 40 ppm alum
Liquid Alum (D)	3.58	0.45	0.75	0.30	100 ppm alk. 40 ppm alum
Liquid Alum (E)	3.56	0.45	0.75	0.30	100 ppm alk. 40 ppm alum
Liquid Alum (F)	2.7	0.50	1.45	0.90	20 ppm alk. 20 ppm alum

* Alkalinity

buffer capacity of 100 ppm alkalinity, did not appear to be significantly affected by the variations in pH of the alums, with a maximum decrease in pH after 15 minutes of 0.4 units. However, a water of lower buffering capacity (20 ppm alkalinity) showed a substantial pH loss of 0.9 units after 15 minutes contact with the low pH alum. In such waters, the use of low pH alum could result in a substantial reduction of pH and alkalinity in the water; floc formation would thus be impeded because the new pH of the water would be outside the optimum range for coagulation and flocculation.

Variations in the specific gravity of liquid alum can also affect the treatment process. If the same dilution of alum is made, regardless of the specific gravity of the batch of alum, the concentration of the solution of alum could vary greatly. Using the regular dilution figure for obtaining a 1% w/v solution, alum of specific gravity 1.306 gave a concentration of 9 mg/mL (Table 14); alum of specific gravity 1.339, when diluted in the same manner, yielded a concentration of 10.15 mg/mL. This difference in concentration could well affect the flocculation process in the treatment of certain waters. Treatment of waters with low dissolved solids, or some other characteristic that would affect flocculating efficiency, necessitating a variation in dose rate of more than eight percent from the optimum, would prove difficult.

It is quite possible that some water plant problems have stemmed from the use of a new batch of alum with a significantly different pH and/or specific gravity from that used previously. If the use of such alum were to coincide with the seasonal changes that alter raw water characteristics, then treatment problems would be inevitable. Knowledge of the variation in alum characteristics would enable such problems to be avoided or minimized.

TABLE 14. SPECIFIC GRAVITY AND CONCENTRATION OF 1% SOLUTIONS OF VARIOUS ALUMS

Location	Specific Gravity	Concentration of 1% w/v solution
Kenora (New)	1.306	9.0
Deseronto	1.339	10.15
Oakville	1.335	10.02
Alexandria	1.335	10.02

B) USE OF LOWER DOSAGES OF PRIMARY COAGULANTS IN TREATMENT

During the latter part of this investigation, when treatment plants were visited, it was noted that a trend towards the use of lower dosage rates of primary coagulants was developing. This was made clear in a presentation given in 1981*. Some plants (e.g. Hamilton) employ only a 5 ppm alum feed 75% of the time the plant is operating; the dosage rate would be increased to 10 ppm when turbidity increased in the raw water.

This trend towards the use of lower chemical dosages, which may not be the optimal dosages, implies that the maximum expected levels of contaminants in water treatment chemicals, that had been calculated (see Discussion - Trace Metal Contamination) on a 50 ppm feed rate could now be recalculated at much lower levels. This would substantially increase the already wide margin of safety in the usage of treatment chemicals. If the trend of low chemical feed rates were to continue, justification of a continuing monitoring program for treatment chemicals, as a procedure to ensure a contaminant-free water supply would be difficult. However, the apparent trend of using lower chemical dosages in water treatment requires some discussion, to determine if it is based on solid technical principles. It may be that economic considerations and the expediency of lengthened filter runs have overridden the requirement for sound technology in water treatment.

Certain chemical principles and a large amount of experimental data provide the following basic tenets that govern efficient water treatment. They are as follows:

1) The velocity of a reaction is primarily dependent on the concentration and temperature of the reactants. Since the temperature of many surface waters, and waters of the

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* "Alternative coagulants and coagulant aids to reduce treatment costs". J. Carnduff. 22nd Water Works Seminar. Ontario Section AWWA Toronto, November 18, 1981.

Great Lakes in particular, is on the low side, then very low dosages of treatment chemicals would require very long retention times for reactions to go to completion.

2) Results in this program indicate that both metals and carbonaceous material in the water become adsorbed onto the chemical floc which settles to form the sludge. Appendices 3C1a through 3C1f show this quite clearly. It could be assumed that optimal floc formation would produce optimal adsorption and therefore removal of these substances, many of which are of health concern.

3) Minimal residuals of aluminum in the finished water are only achieved at the optimum dosage of alum. A greater percentage of the added aluminum is left in solution at low dosages, which has the potential to cause problems in the distribution system.

It would, therefore, seem reasonable that optimal dosages of alum should be used during the treatment of water.

REFERENCES

1. Outlines of Analytical Methods, Ontario Ministry of the Environment, Labaratory Services Branch, June 1981.

2. Ontario Drinking Water Objectives, Ontario Ministry of the Environment, revised 1983.

APPENDIX 1

A.1. TRACE METALS IN SAMPLES OF LIQUID ALUMINUM SULPHATE AND FERRIC CHLORIDE SUPPLIED BY CHEMICAL MANUFACTURERS

Material	Aluminum Sulphate (AN1)	Aluminum Sulphate (AC1)	Ferric Chloride (FC1)
Trace Metals (ppm as metal)+			
Cadmium	<0.1	<0.1	<0.25
Chromium	<0.42	50	15
Cobalt	<0.4	<0.4	2.8
Copper	1.6	1.3	21
Lead	<0.63	3.3	<0.15
Manganese	0.52	7.8	-#
Molybdenum	0.76	0.89	5.2
Nickel	2.0	0.7	13
Tin	1.9	1.6	ND*
Zinc	4.4	0.6	6.2

# result not available

+ analysis by emission spectrography

* not detected

APPENDIX 1

A.2. SPECIFIC GRAVITY OF SAMPLES OF LIQUID ALUMINUM SULPHATE AND FERRIC CHLORIDE SUPPLIED BY CHEMICAL MANUFACTURERS

Material	Aluminum Sulphate (AN1)	Aluminum Sulphate (AC1)	Ferric Chloride (FC1)
Specific Gravity @ 20°C	1.323	1.330	1.385

APPENDIX 2

A.1. TRACE METALS IN SAMPLES OF ALUMINUM SULPHATE AND FERRIC CHLORIDE DELIVERED TO SIX WATER TREATMENT PLANTS

Material	Liquid Aluminum Sulphate			Liquid Ferric Chloride		
Trace Metals (ppm as metal)+	AC2	AC3	AC4	FC2	FC3	FC4
Aluminum	-#	**	**	-	240	*
Antimony	-	<100	<100	-	<80	<30
Arsenic	-	<300	<300	-	<240	<300
Barium	-	<30	<30	-	<240	<10
Beryllium	-	<1.0	<1.0	-	<80	<10
Bismuth	-	<10	<10	-	<80	<30
Boron	-	<10	<10	-	<80	<10
Calcium	-	<30	<30	-	80-240	*
Cadmium	0.67	<10	<10	<0.25	<80	<10
Chromium	50	<10	<10	18	<80	tr to <10
Cobalt	0.52	<30	<30	2.5	-	<10
Copper	0.67	∿<1	∿<1	0.89	tr to <80	30-100
Gallium	-	<10	<10	-	<80	<10
Germanium	-	<10	<10	-	<80	<10
Indium	-	<10	<10	-	<80	*
Iron	-	<10	100-300	-	>>>80	**
Lead	0.25	<10	<10	<1.5	<80	tr to <10
Magnesium	-	∿1	1-10	-	∿240	*
Manganese	-	∿10	∿<10	-	240-800	*
Mercury	*	<300	<300	*	<240	*
Molybdenum	0.15	<10	<10	4.2	<240	<10
Nickel	1.3	<10	<10	10	<80	tr to <10
Silicon	-	<300	<300	-	800-2400	*
Silver	-	<1	<1	-	<80	<10
Strontium	-	<300	<300	-	<80	∿100
Tellurium	-	<10	<10	-	<80	<10
Tin	-	<10	<10	-	<80	<30
Titanium	-	tr to <30	tr to <30	-	∿240	*
Vanadium	-	<10	<10	-	<80	<10
Zinc	2.6	<300	<300	3.4	-	<300
Zirconium	-	<100	<100	-	<240	*

* interference

** matrix

+ analysis by emission spectrography

# results not available

tr = trace

APPENDIX 2

A.2. SPECIFIC GRAVITY OF SAMPLES OF ALUMINUM SULPHATE AND FERRIC CHLORIDE SUPPLIED TO SIX WATER TREATMENT PLANTS

Material	Liquid Aluminum Sulphate			Liquid Ferric Chloride		
	AC2	AC3	AC4	FC2	FC3	FC4
Specific Gravity @ 20°C	1.325	1.321	1.332	1.377	1.408	1.419
Percent Al	*	*	*	-	-	-
Percent Fe	-	-	-	*	*	*

* Gravimetric method not set up; colorimetric method under development

APPENDIX 2

B.1. TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AT THE TORONTO, (R.C. HARRIS) WATER PLANT

Sample	Water		Plant
Trace Metals (ppm as metal)+	Raw	Treated	Sludge
Aluminum	0.03	0.03	2400
Antimony	- #	-	-
Arsenic	0.004	0.004	2.9
Barium	0.02	0.02	*
Beryllium	<0.0003	<0.0003	*
Bismuth	-	-	-
Boron	0.21	0.004	*
Calcium	-	-	7000
Cadmium	<0.005	<0.005	<0.02
Chromium	0.004	0.004	6.7
Cobalt	-	-	-
Copper	0.009	0.009	2.0
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	0.04	0.02	2300
Lead	0.008	0.007	12.0
Magnesium	7.0	6.5	1200
Manganese	0.002	0.001	59
Mercury	<0.00008	<0.00008	-
Molybdenum	0.0025	0.0025	0.9
Nickel	0.0031	0.0036	2.3
Silicon	-	-	-
Silver	-	-	-
Strontium	0.15	0.15	*
Tellurium	-	-	-
Tin	-	-	-
Titanium	0.0025	0.0025	68
Vanadium	0.002	0.002	*
Zinc	0.005	0.005	21
Zirconium	-	-	-

* interference

+ analysis by emission spectrography

# result not available

APPENDIX 2

B.2. GAS CHROMATOGRAPHY ANALYSIS OF METHYLENE CHLORIDE EXTRACTS OF RAW AND TREATED WATERS AND SLUDGES FROM THREE WATER TREATMENT PLANTS.

Chemical	2,4-DNT[1] (ppm)	2,6-DNT[2] (ppm)	TNT[3] & Unknowns (ppm)
Water Plant Sample			
Verner Raw Water	ND*	ND	ND
Treated Water	ND	ND	ND
Sludge	ND	ND	ND
Toronto (R.C. Harris) Raw Water	ND	ND	ND
Treated Water	ND	ND	ND
Sludge	ND	ND	ND
Toronto (R.L. Clark) Raw Water	ND	ND	ND
Treated Water	ND	ND	ND
Sludge	0.2	0.3	0.04

*not detectable
1=2,4-dinitrotoluene
2=2,6-dinitrotoluene
3=trinitrotoluene

APPENDIX 2

C.1. GAS CHROMATOGRAPHY ANALYSIS OF METHYLENE CHLORIDE EXTRACTS OF HYDROFLUOROSILICIC ACID SUPPLIED TO WATER PLANTS.

Chemical	2,4-DNT[1] (ppm)	2,6-DNT[2] (ppm)	TNT[3] & Unknowns (ppm)
Sample			
AK 4	<1	ND*	ND
AL 1	"	"	"
AL 2	"	"	"
AL 3	"	"	"
BA 1	"	"	"
BA 2	"	"	"
BA 3	"	"	"
BA 4	"	"	"
BA 5			

1=2,4-dinitrotoluene
2=2,6-dinitrotoluene
3=trinitrotoluene
* not detectable

APPENDIX 3

A.1.a TRACE METALS IN SAMPLES OF ALUMINUM SULPHATE DELIVERED TO EIGHT WATER TREATMENT PLANTS

Material Liquid Aluminum Sulphate

Trace Metals (ppm as metal)+	AC5	AC6	AC7	AC8	AN2	AB1	AC9	AC10
Aluminum	**	**	**	**	**	**	**	**
Antimony	<10	<10	<10	<100	<20	<20	<20	<20
Arsenic	<30	<30	<30	<300	<20	<20	<20	<20
Barium	<30	<30	<30	<30	<20	<20	<20	<20
Beryllium	<1.0	<1.0	<1.0	<1.0	<20	<20	<20	<20
Bismuth	<10	<10	<10	<10	<20	<20	<20	<20
Boron	<10	<10	<10	<10	<20	<20	<20	<20
Calcium	300-1000	300-1000	300-1000	~300	~20	20-60	~60	20-60
Cadmium	<10	<10	<10	<10	<20	<20	<20	<20
Chromium	100-300	100-300	100-300	100-300	<20	<20	~60	<20
Cobalt	<10	<10	<10	<30	<20	<20	<20	<20
Copper	<10	<10	<10	~<1.0	tr-<20	tr-<20	tr-<20	tr-<20
Gallium	<10	<10	<10	<10	<20	<20	<20	<20
Germanium	<10	<10	<10	<10	<20	<20	<20	<20
Indium	<10	<10	<10	<10	<20	<20	<20	<20
Iron	>1000	>1000	~>1000	300-1000	100-200	200-660	>2000	>2000
Lead	<10	<10	<10	<10	<20	<20	<20	<20
Magnesium	10-30	30-100	30-100	~10	tr-<20	20-60	tr-<20	tr-<20
Manganese	<10	~10	~10	~10	tr-<20	tr-<20	~20	~20
Mercury	<100	<100	<100	<300	<200	<200	<200	<200
Molybdenum	<10	<10	<10	<10	<20	<20	<20	<20
Nickel	<10	<10	<10	<10	tr-<20	tr-<20	tr-<20	tr-<20
Silicon	10-100	10-100	10-100	<300	tr-<20	tr-<20	tr-<20	tr-<20
Silver	<10	<10	<10	<1.0	<20	<20	<20	<20
Strontium	<30	<30	<30	<300	<20	<20	<20	<20
Tellurium	<10	<10	<10	<10	<20	<20	<20	<20
Tin	<10	<10	<10	<10	<20	<20	<20	<20
Titanium	300-1000	300-1000	100-300	<300	<20	<20	~200	60-200
Vanadium	10-30	10-30	10-30	10-30	~<20	<20-60	20-60	tr-<20
Zinc	<300	<300	<300	<300	-#	-	-	-
Zirconium	<10	<10	<10	<100	<20	<20	<20	<20

** matrix

+ analysis by emission spectrography

# result not available

tr = trace

APPENDIX 3

A.1.b. TRACE METALS IN SAMPLES OF FERRIC CHLORIDE DELIVERED TO TWO WATER TREATMENT PLANTS

Material	Liquid Ferric Chloride	
Trace Metals (ppm as metal)+	FC5	FC6
Aluminum	*	*
Antimony	<30	<30
Arsenic	<300	<300
Barium	<10	<10
Beryllium	<10	<10
Bismuth	<30	<30
Boron	30-100	30-100
Calcium	*	*
Cadmium	<10	<10
Chromium	∿10	∿10
Cobalt	10-30	10-30
Copper	30-100	10-30
Gallium	<10	<10
Germanium	<10	<10
Indium	*	*
Iron	**	**
Lead	10-30	<10
Magnesium	*	*
Manganese	*	*
Mercury ++	0.0005	0.05
Molybdenum	<10	<10
Nickel	10-30	10-30
Silicon	*	*
Silver	<10	<10
Strontium	<100	<100
Tellurium	<10	<10
Tin	<30	<30
Titanium	*	*
Vanadium	10-30	10-30
Zinc	<300	-#
Zirconium	*	*

* interference

** matrix

+ analysis by emission spectrography

++ analysis by flameless atomic absorption

# result not available

APPENDIX 3

A.2. SPECIFIC GRAVITIES OF SAMPLES OF ALUMINUM SULPHATE AND FERRIC CHLORIDE SUPPLIED TO WATER PLANTS.

Sample	Specific Gravity @ 20°C	
Liquid Aluminum Sulphate	AC5	1.333
"	AC6	1.329
"	AC7	1.333
"	AC8	1.334
"	AN2	1.325
"	AB1	1.310
"	AC9	1.335
"	AC10	1.327
Liquid Ferric Chloride	FC5	1.372
"	FC6	1.448

APPENDIX 3

A.3. GAS CHROMATOGRAPHY ANALYSIS OF METHYLENE CHLORIDE EXTRACTS OF PRIMARY COAGULANTS FROM SELECTED WATER TREATMENT PLANTS.

Chemical		2,4-DNT[1] (ppm)	2,6-DNT[2] (ppm)	TNT[3] & Unknowns (ppm)
Sample				
Liquid Aluminum Sulphate	AB1	ND*	ND	ND
" " "	AN3	ND	ND	ND
" " "	AC5	ND	ND	ND
Liquid Ferric Chloride	FC5	ND	ND	ND
" " "	FC6	ND	ND	ND

*not detected
1=2,4-dinitrotoluene
2=2,6-dinitrotoluene
3=trinitrotoluene

APPENDIX 3

A.4. PERCENT MOISTURE, LOSS ON IGNITION AND TOTAL CARBON ANALYSIS OF ALUMINUM SULPHATE AND FERRIC CHLORIDE FROM SELECTED WATER TREATMENT PLANTS

Analysis		Percent Moisture @ 105°C	Percent Loss on Ignition	Total Carbon (ppm)
Sample				
Liquid Aluminum Sulphate	AC3	60.0	11.6	20
"	AC4	-#	-	36
"	AC5	67.8	-	-
"	AC6	69.1	14.4	-
"	AC7	46.7	13.4	-
"	AC8	59.5	13.8	-
"	AB1	64.0	9.36	8
"	AC9	54.0	16.6	16
Liquid Ferric chloride	FC7	67.4	5.1	-

# - result not available

APPENDIX 3

A.5. INFRARED ANALYSIS OF METHYLENE CHLORIDE EXTRACTS AND DOC OF ALUMINUM SULPHATE AND FERRIC CHLORIDE FROM SELECTED WATER TREATMENT PLANTS.

Analysis		DOC (ppm)*
Sample		
Aluminum sulphate,	Elgin area	3.7
" "	Owen Sound	3.7
" "	Sarnia	5.0
" "	Goderich	4.2
" "	Port Elgin	3.5
" "	R. L. Clark (Toronto)	2.1
Ferric chloride,	Grand Bend	-#

* dissolved organic carbon, carried out on appropriate dilutions
** infrared scan
# result not available

APPENDIX 3

B.1. TRACE METALS IN VARIOUS TREATMENT AIDS AT SELECTED WATER TREATMENT PLANTS

Material	Activated Carbon	Unslaked Lime	Polymer Cat Floc T	Sodium Bicarbonate	Sodium Hydroxide
Trace Metals (ppm as metal)+					
Aluminum	130.0	100-300	∿1200	<10	1-3
Antimony	-#	<10	<400	<10	<50
Arsenic	<0.2	<100	<120	<100	<100
Barium	<4.0	<10	<40	<10	<10
Beryllium	<0.5	<10	<12	<10	<0.5
Bismuth	-	<10	<12	<10	-
Boron	<4.0	<10	tr-<12	<10	3-10
Calcium	1800.0	**	8000-16000	30-100	3-10
Cadmium	0.1	<10	<12	<10	<10
Chromium	2.5	<10	<12	<10	tr-<0.5
Cobalt	-	<10	-	<10	<1.0
Copper	0.9	<10	12	<10	0.5-1.0
Gallium	-	<10	<12	<10	-
Germanium	-	<10	<12	<10	<10
Indium	-	*	<12	Int	-
Iron	540.0	300-1000	1200-4000	<10	10-20
Lead	<0.4	<10	∿40	<10	<10
Magnesium	100.0	∿>1000	∿800	∿10	tr-0.5
Manganese	16.0	10	tr-<12	<10	tr-0.5
Mercury	-	<300	<400	<100	-
Molybdenum	0.7	<10	<40	<10	<1
Nickel	3.1	tr-<10	tr-<12	<10	<3
Silicon	-	∿1000	120-400	tr-<10	∿50
Silver	-	<1	tr-<12	<10	<0.5
Strontium	2.4	<100	<120	<100	3-10
Tellurium	-	<10	<12	<10	<10
Tin	-	<10	<12	<10	<10
Titanium	8.0	tr-<10	<12	<10	<0.5
Vanadium	<2.0	<10	<12	<10	-
Zinc	0.78	*	-	<300	<10
Zirconium	-	<10	<40	<10	<3

** matrix

+ analysis by emission spectrography

# result not available

* interference

tr = trace

APPENDIX 3

B.2. PERCENT MOISTURE AND LOSS ON IGNITION OF A SAMPLE OF ACTIVATED CARBON

Parameter	Percent Moisture 105°C	Percent Loss on Ignition
Material		
Activated Carbon	82.0	7.2

APPENDIX 3

B.3. INFRARED ANALYSIS OF METHYLENE CHLORIDE EXTRACTS AND DOC OF TREATMENT AIDS FROM SELECTED WATER TREATMENT PLANTS.

Analysis	DOC (ppm)*	Methylene Chloride Extract IR Scan**
Material		
Activated carbon (Elgin Area W.S.)	NA	NA
Sodium bicarbonate (Port Elgin)	NA	+

NA methodology not applicable
+ extracted organics not identifiable
* dissolved organic carbon
** infrared scan

APPENDIX 3

C.1.a TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE GODERICH WATER PLANT

Material	Raw Water	Treated Water	Sludge
Trace Metals (ppm as metal)+			
Aluminum	0.076	0.072	2400
Antimony	- #	-	-
Arsenic	0.004	<0.0025	*
Barium	0.01	0.01	<4.0
Beryllium	<0.0003	<0.0003	<0.5
Bismuth	-	-	-
Boron	0.006	0.006	<4.0
Calcium	-	-	3200
Cadmium	<0.0005	<0.0005	<0.02
Chromium	0.003	0.003	4.9
Cobalt	-	-	-
Copper	0.46	0.02	0.6
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	0.085	0.019	530
Lead	0.0095	0.006	5.6
Magnesium	6.3	6.2	1345.0
Manganese	0.003	0.0015	14.0
Mercury	-	-	-
Molybdenum	0.002	<0.0015	0.7
Nickel	<0.0025	0.002	0.98
Silicon	-	-	-
Silver	-	-	-
Strontium	0.1	0.1	<1.6
Tellurium	-	-	-
Tin	-	-	-
Titanium	0.0025	0.0025	8.8
Vanadium	0.002	0.002	<4.0
Zinc	0.009	0.01	2.8
Zirconium	-	-	-

* interference

+ analysis by emission spectrography

# result not available

APPENDIX 3

C.1.b TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE GRAND BEND WATER PLANT

Material	Raw Water	Treated Water	Sludge
Trace Metals			
(ppm as metal)+			
Aluminum	0.07	0.18	4300
Antimony	- #	-	-
Arsenic	0.003	<0.0025	*
Barium	0.014	0.015	*
Beryllium	<0.0003	<0.0003	*
Bismuth	-	-	-
Boron	0.006	0.008	*
Calcium	-	-	10000
Cadmium	0.0005	0.0005	0.6
Chromium	0.0025	0.008	9.3
Cobalt	-	-	-
Copper	0.04	0.03	<0.04
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	0.1	1.1	3500
Lead	0.007	0.009	14.7
Magnesium	6.4	6.3	5000
Manganese	0.004	0.011	70
Mercury	-	-	-
Molybdenum	0.002	0.003	1.6
Nickel	<0.0025	<0.0025	3.9
Silicon	-	-	-
Silver	-	-	-
Strontium	0.09	0.09	*
Tellurium	-	-	-
Tin	-	-	-
Titanium	<0.0025	0.006	28
Vanadium	<0.0015	<0.0015	*
Zinc	0.009	0.02	14
Zirconium	-	-	-

* interference

+ analysis by emission spectrography

# result not available

APPENDIX 3

C.1.c TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE OWEN SOUND WATER PLANT

Material	Raw Water	Treated Water	Sludge
Trace Metals			
(ppm as metal)+			
Aluminum	0.13	0.07	1200
Antimony	- #	-	-
Arsenic	<0.0025	<0.0025	0.26
Barium	0.015	0.014	<4
Beryllium	<0.0003	<0.0003	<0.5
Bismuth	-	-	-
Boron	0.08	0.01	<4
Calcium	-	-	250
Cadmium	<0.0005	<0.0005	0.51
Chromium	0.002	0.002	1.8
Cobalt	-	-	-
Copper	0.17	0.04	0.05
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	0.21	0.02	240
Lead	0.004	0.007	<0.4
Magnesium	5.9	5.9	130
Manganese	0.010	<0.0005	6.7
Mercury	-	-	-
Molybdenum	<0.0015	<0.0015	<0.1
Nickel	<0.0025	<0.0025	0.66
Silicon	-	-	-
Silver	-	-	-
Strontium	0.076	0.074	<1.6
Tellurium	-	-	-
Tin	-	-	-
Titanium	<0.0025	<0.0025	<4
Vanadium	<0.0015	<0.0015	<2
Zinc	0.01	0.0095	1.0
Zirconium	-	-	-

+ analysis by emission spectrography

# result not available

APPENDIX 3

C.1.d TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE PORT ELGIN WATER PLANT

Material	Raw Water	Treated Water	Sludge
Trace Metals			
(ppm as metal)+			
Aluminum	0.034	0.12	2500
Antimony	- #	-	-
Arsenic	<0.0025	<0.0025	*
Barium	0.014	0.014	<4
Beryllium	<0.0003	<0.0003	<0.5
Bismuth	-	-	-
Boron	0.05	0.007	<4
Calcium	-	-	310
Cadmium	<0.0005	<0.0005	<0.02
Chromium	0.003	0.003	4.1
Cobalt	-	-	-
Copper	0.034	0.036	0.72
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	0.042	0.071	120
Lead	0.006	0.0075	1.1
Magnesium	6.5	6.4	140
Manganese	0.012	0.004	2.1
Mercury	-	-	-
Molybdenum	<0.0015	<0.0015	<0.1
Nickel	<0.0025	<0.0025	1.1
Silicon	-	-	-
Silver	-	-	-
Strontium	0.10	0.10	<1.6
Tellurium	-	-	-
Tin	-	-	-
Titanium	<0.0025	<0.0025	6.4
Vanadium	<0.0015	0.002	<2
Zinc	0.01	0.009	1.3
Zirconium	-	-	-

* interference

+ analysis by emission spectrography

# result not available

APPENDIX 3

C.1.e TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE SARNIA WATER PLANT

Material	Raw Water	Treated Water	Sludge
Trace Metals			
(ppm as metal)+			
Aluminum	0.009	0.13	1570
Antimony	- #	-	-
Arsenic	<0.0025	<0.0025	*
Barium	0.014	0.012	<4
Beryllium	<0.0003	<0.0003	<0.5
Bismuth	-	-	-
Boron	0.004	<0.0025	<4
Calcium	-	-	450
Cadmium	<0.0005	<0.0005	0.1
Chromium	<0.0005	<0.0005	3.5
Cobalt	-	-	-
Copper	0.079	0.022	1.1
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	0.03	0.045	320
Lead	<0.0025	<0.0025	<0.4
Magnesium	5.7	5.0	220
Manganese	0.0015	0.001	7.6
Mercury	-	-	-
Molybdenum	<0.0015	<0.0015	<0.1
Nickel	<0.0025	<0.0025	0.98
Silicon	-	-	-
Silver	-	-	-
Strontium	0.087	0.073	<1.6
Tellurium	-	-	-
Tin	-	-	-
Titanium	<0.0025	<0.0025	4.8
Vanadium	<0.0015	<0.0015	<2
Zinc	0.011	0.006	3.0
Zirconium	-	-	-

* interference

+ analysis by emission spectrography

# result not available

APPENDIX 3

C.1.f TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE TORONTO (R.L. CLARK) WATER PLANT

Material	Raw Water	Treated Water	Sludge
Trace Metals			
(ppm as metal)+			
Aluminum	<0.05	0.05	640
Antimony	- #	-	-
Arsenic	<0.05	<0.05	0.73
Barium	<0.05	<0.05	-
Beryllium	<0.006	<0.006	-
Bismuth	<0.1	<0.1	-
Boron	<0.05	<0.05	-
Calcium	>15	>15	860
Cadmium	<0.01	<0.01	<0.02
Chromium	<0.01	<0.01	1.8
Cobalt	<0.01	<0.01	-
Copper	0.38	<0.05	0.93
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	<0.05	<0.05	555
Lead	<0.05	<0.05	1.4
Magnesium	6.3	6.8	190
Manganese	<0.01	<0.01	16.5
Mercury	-	-	-
Molybdenum	<0.003	<0.003	<0.12
Nickel	<0.005	<0.005	1.0
Silicon	-	-	-
Silver	-	-	-
Strontium	0.14	0.15	-
Tellurium	-	-	-
Tin	-	-	-
Titanium	<0.05	<0.05	-
Vanadium	<0.03	<0.03	-
Zinc	<0.02	<0.02	5.5
Zirconium	-	-	-

+ analysis by emission spectrography

# result not available

APPENDIX 3

C.1.g MERCURY IN RAW AND TREATED WATERS FROM SELECTED WATER TREATMENT PLANTS

Plant		Mercury ppb*
Elgin Area W.S.	Raw	<0.04
	Treated	<0.04
Toronto (R.L. Clark)	Raw	0.05
	Treated	0.05
Sarnia	Raw	<0.04
	Treated	<0.04
Owen Sound	Raw	<0.03
	Treated	<0.03
Grand Bend	Raw	<0.04
	Treated	<0.04
Goderich	Raw	<0.04
	Treated	<0.04
Port Elgin	Raw	<0.03
	Treated	<0.03

* analysis by flameless atomic absorption; detection limit 0.02 to 0.04 ppb.

C.2. ANALYSIS FOR GENERAL CHEMICAL PARAMETERS IN RAW AND TREATED WATERS FROM SEVEN WATER TREATMENT PLANTS

Parameter	pH	Hardness ppm $CaCO_3$	Alkalinity ppm $CaCO_3$	Iron ppm Fe	Chloride ppm Cl	Turbidity FTU	Conductivity umhos/cm	Dissolved Solids ppm
Plant								
Elgin Area W.S.								
Raw	8.1	129	99	0.31	18	4.4	285	185
Treated	8.0	138	99	0.01	19	0.86	305	200
Toronto (R.L. Clark)								
Raw	8.2	136	95	0.25	29	7	325	190
Treated	8.1	137	92	0.05	28	<1.0	325	185
Sarnia								
Raw	8.0	98	81	0.01	8	0.7	205	133
Treated	8.2	99	80	<0.01	7	0.3	208	135
Owen Sound								
Raw	7.8	95	66	0.21	6	0.67	200	130
Treated	8.2	93	73	0.04	5	1.7	189	125
Grand Bend*								
Raw	8.1	101	83	0.12	7	1.7	209	135
Treated	8.1	104	78	1.2	10	2.8	210	135
Goderich								
Raw	8.2	99	80	0.06	7	1.4	208	135
Treated	7.8	100	70	<0.01	8	0.3	215	140
Port Elgin								
Raw	7.3	102	83	0.04	6	1.0	196	125
Treated	7.7	100	70	<0.01	7	0.43	200	130

* uses ferric chloride for coagulation

APPENDIX 3

C.3. DISSOLVED ORGANIC CARBON IN RAW AND TREATED WATERS FROM SELECTED WATER TREATMENT PLANTS

Plant		DOC ppm
Elgin Area W.S.	Raw	1.8
	Treated	1.8
Toronto (R.L. Clark)	Raw	1.8
	Treated	1.8
Sarnia	Raw	1.5
	Treated	1.5
Owen Sound	Raw	1.6
	Treated	1.3
Grand Bend	Raw	1.8
	Treated	1.8
Goderich	Raw	1.7
	Treated	1.3
Port Elgin	Raw	1.2
	Treated	1.0

APPENDIX 3

C.4. PERCENT MOISTURE, LOSS ON IGNITION AND TOTAL CARBON IN SELECTED WATER PLANT SLUDGES

Parameter	Percent Moisture @ 105°C	Percent Loss on Ignition	Total Carbon ppm
Plant			
Elgin Area W.S.	89.0	0.55	0.42
Sarnia	66.3	-#	-
Owen Sound	47.7	-	-
Goderich	81.0	-	-
Port Elgin	99.2	0.19	-

# result not available

APPENDIX 3

C.5. INFRARED ANALYSIS OF AND WEIGHT OF EXTRACTABLE MATERIAL FROM METHYLENE CHLORIDE EXTRACTS OF SLUDGES FROM SELECTED WATER TREATMENT PLANTS

Plant	PARAMETER Weight of extract*	IR Scan
Elgin Area W.S.	790	+
Owen Sound	10	+
Grand Bend	360	+
Sarnia	4000	+
Goderich	33	+
Port Elgin	-#	+
Toronto (R.L. Clark)	-	+

# result not available

+ extracted organics not identifiable

* mg/Kg dried weight of sludge

APPENDIX 3

D.1. TRACE METALS IN FIVE SAMPLES OF FLUORIDATING CHEMICALS FROM SELECTED WATER TREATMENT PLANTS

Material	Hydrofluorosilicic Acid			Sodium Silicofluoride	
Trace Metals (ppm as metal)+	HA1	HA2	HA3	NS1	NS2
Aluminum	>27	18	14	5-10	<400
Antimony	<0.27	-	-	<10	<40
Arsenic	∿0.8	96	97	<100	<120
Barium	2.7-8.0	0.17	0.16	<10	<12
Beryllium	<0.27	-	-	<10	<12
Bismuth	<0.27	-	-	<10	<12
Boron	0.27	-	-	<10	<12
Calcium	>27	-	-	∿10	400-1200
Cadmium	<0.27	0.02	0.02	<10	<12
Chromium	∿0.27	0.33	0.34	<10	tr.-<40
Cobalt	- #	-	-	<10	-
Copper	∿2.7	1.5	1.4	<10	tr.-<12
Gallium	<0.27	-	-	<10	<12
Germanium	<0.27	-	-	<10	<40
Indium	<0.27	-	-	*	<12
Iron	>27	34	24	<10	∿40
Lead	tr.-<0.27	0.09	0.09	<10	<12
Magnesium	>27	16	15	tr.-<10	<40
Manganese	0.27-0.80	0.88	0.64	<10	40-120
Mercury	<0.8	-	-	<100	<400
Molybdenum	<0.8	0.03	0.03	<10	<12
Nickel	0.8-2.7	0.89	1.1	tr.-<10	tr.-<12
Silicon	>27	-	-	**	**
Silver	<0.27	-	-	tr.-<10	tr.-<12
Strontium	0.27-0.8	-	-	tr.-<30	<12
Tellurium	<0.27	-	-	<10	<40
Tin	<0.27	-	-	<10	<40
Titanium	8-27	-	-	<10	tr.-<12
Vanadium	∿0.27	-	-	<10	<12
Zinc	-	0.4	0.4	<300	-
Zirconium	<0.8	-	-	<10	<12

* interference

** matrix

+ analysis by emission spectrography

# result not available

tr = trace

APPENDIX 4

A.1.a TRACE METALS IN SAMPLES OF ALUMINUM SULPHATE DELIVERED TO SELECTED WATER TREATMENT PLANTS

Material Liquid Aluminum Sulphate

Trace Metals (ppm as metal)+	AC11	AC12	AN3	AC13	AB2	AB3
Aluminum	**	**	**	**	**	**
Antimony	<20	<20	<20	<20	-#	-
Arsenic	<60(0.06)	<60(0.08)	<60(0.07)	<60(0.08)	-	-
Barium	<20	<20	<20	<20	-	-
Beryllium	<2	<2	<2	<2	-(<0.03)	-(<0.03)
Bismuth	<20	<20	<20	<20	-	-
Boron	<20	<20	<20	<20	-	-
Calcium	60-200	60-200	600-2000	600-2000	-(30.8)	-(30.3)
Cadmium	<20(<0.05)	<20(0.05)	<20(0.083)	<20(<0.03)	-(<0.05)	-(<0.05)
Chromium	6-20(31.5)	20-40(42.0)	20-60(34.0)	20-60(41.0)	-(0.41)	-(0.18)
Cobalt	- (<0.2)	- (<2.0)	- (<0.2)	- (<0.2)	- (<0.5)	- (<0.5)
Copper	tr-<20(4.5)	tr-<20(3.8)	<20(<0.05)	<20 (<0.05)	-(1.25)	- (1.82)
Gallium	-	-	-	-	-	-
Germanium	<20	<20	<20	<20	-	-
Indium	<20	<20	<20	<20	-	-
Iron	>2000	>2000	>2000	>2000	1.09	0.73
Lead	<6 (2.9)	<6 (1.8)	<6 (72.0)	<6 (96.0)	- (1.25)	-(<0.6)
Magnesium	<20	<20	<20	<20	- (42.7)	-(41.8)
Manganese	∿20 (-)	20-60 (-)	20-60 (-)	60-120 (-)	- (2.77)	-(1.95)
Mercury	<200(-)	<200 (-)	<200 (-)	<200 (-)	- (0.00037)	-(0.0012)
Molybdenum	<20 (2.4)	<20 (1.8)	<20 (11)	<20 (14)	-	-
Nickel	<20 (3.6)	<20 (3.9)	<20 (0.5)	<20 (0.35)	-(<0.5)	- (<0.5)
Silicon	-	-	-	-	-	-
Silver	<20 (-)	<20 (-)	<20 (-)	<20 (-)	-	-
Strontium	<60 (-)	<60 (-)	<20 (-)	<60 (-)	-(0.39)	-(0.39)
Tellurium	<20	<20	<20	<20	-	-
Tin	<20	<20	<20	<20	-	-
Titanium	6-20	20-60	600-2000	600-2000	-(1.63)	-(1.79)
Vanadium	10-30	10-20	10-30	10-30	-(2.69)	-(2.43)
Zinc	-(2.6)	-(1.6)	-(<0.25)	-(<0.25)	-(<0.25)	-(0.88)
Zirconium	<20	<20	<20	<20	-	-

+ analysis by emission spectrography

# results not available

** matrix

tr = trace

NB Numbers in parenthesis give the results of atomic absorption analysis

APPENDIX 4

A.1.a Cont'd

Material Liquid Aluminum Sulphate

Trace Metals (ppm as metal)+	AB4	AB5	AB6	AC16	AC17	AC18
Aluminum	**	**	**	**	**	- #
Antimony	-	-	-	-	-	-
Arsenic	-	-	-	-	-	-
Barium	-	-	-	-	-	-
Beryllium	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.03)
Bismuth	-	-	-	-	-	-
Boron	-	-	-	-	-	-
Calcium	-(42.3)	-(34.2)	-(51.2)	-(23.6)	-(58.7)	-(53.6)
Cadmium	-(<0.05)	-(<0.05)	-(0.05)	-(<0.05)	-(<0.05)	-(0.06)
Chromium	-(0.51)	-(0.45)	-(5.3)	-(14.9)	-(47.0)	-(47.0)
Cobalt	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)
Copper	-(1.13)	-(1.10)	-(1.35)	-(1.97)	-(1.87)	-(1.67)
Gallium	-	-	-	-	-	-
Germanium	-	-	-	-	-	-
Indium	-	-	-	-	-	-
Iron	0.36	1.0	99	264	1130	944
Lead	-(1.13)	-(<0.6)	-(1.63)	-(tr-<0.6)	-(10.6)	-(12.9)
Magnesium	-(46.4)	-(44.3)	-(47.6)	-(10.7)	-(20.8)	-(20.5)
Manganese	-(2.32)	-(2.44)	-(9.05)	-(7.25)	-(6.51)	-(13.8)
Mercury	-(0.00037)	-(0.00061)	-(0.00032)	-(0.0033)	-(0.00032)	-(0.00037)
Molybdenum	-	-	-	-	-	-
Nickel	-(<0.5)	-(<0.5)	-(<0.5)	-(1.6)	-(<0.5)	-(<0.5)
Silicon	-	-	-	-	-	-
Silver	-	-	-	-	-	-
Strontium	-(0.48)	-(0.41)	-(0.45)	-(0.45)	-(1.17)	-(1.0)
Tellurium	-	-	-	-	-	-
Tin	-	-	-	-	-	-
Titanium	-(1.98)	-(1.82)	-(6.17)	-(11.7)	-(66.2)	-(45.6)
Vanadium	-(2.59)	-(2.59)	-(4.86)	-(9.89)	-(26.8)	-(26.6)
Zinc	-(0.25)	-(0.75)	-(1.25)	-(0.63)	-(26.4)	-(2.8)
Zirconium	-	-	-	-	-	-

** matrix

NB Numbers in parenthesis give the results of atomic absorption analysis

+ analysis by emission spectrography

# result not available

tr = trace

APPENDIX 4

A.1.a Cont'd

Material Liquid Aluminum Sulphate

Trace Metals (ppm as metal)+	AN6	AB19	AB20	AC21	AC22	AC23	AC24
Aluminum	- #	-	-	-	-	-	-
Antimony	-	-	-	-	-	-	-
Arsenic	-	-	-	-	-	-	-
Barium	-	-	-	-	-	-	-
Beryllium	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.03)
Bismuth	-	-	-	-	-	-	-
Boron	-	-	-	-	-	-	-
Calcium	-(15.9)	-(108)	-(97.4)	-(88.0)	-(150.)	-(180.)	-(78.7)
Cadmium	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)	-(0.05)
Chromium	-(1.8)	-(45.)	-(50.)	-(43.)	-(43.)	-(-)	-(-)
Cobalt	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)
Copper	-(2.14)	-(1.18)	-(1.69)	-(1.36)	-(1.29)	-(1.52)	-(0.74)
Gallium	-	-	-	-	-	-	-
Germanium	-	-	-	-	-	-	-
Indium	-	-	-	-	-	-	-
Iron	-(2.91)	-(770)	-(1020)	-(780)	-(779)	-(831)	-(890)
Lead	-(0.88)	-(<0.6)	-(<0.6)	-(0.88)	-(<0.6)	-(<0.6)	-(1.13)
Magnesium	-(8.13)	-(39.1)	-(43.)	-(26.5)	-(43.9)	-(64.4)	-(20.3)
Manganese	-(3.25)	-(13.7)	-(9.59)	-(14.4)	-(43.9)	-(64.4)	-(20.3)
Mercury	-(0.05)	-(0.00065)	-(0.00091)	-(0.00049)	-(0.0007)	-(0.0005)	-(0.00055)
Molybdenum	-	-	-	-	-	-	-
Nickel	-(1.5)	-(0.5)	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)
Silicon	-	-	-	-	-	-	-
Silver	-	-	-	-	-	-	-
Strontium	-(0.28)	-(0.79)	-(0.81)	-(0.88)	-(1.09)	-(1.09)	-(1.01)
Tellurium	-	-	-	-	-	-	-
Tin	-	-	-	-	-	-	-
Titanium	-(2.15)	-(70.1)	-(84.2)	-(72.3)	-(62.6)	-(76.7)	-(45.3)
Vanadium	-(2.85)	-(22.3)	-(26.4)	-(22.9)	-(22.8)	-(23.8)	-(25.8)
Zinc	-(1.6)	-(1.6)	-(5.9)	-(0.75)	-(0.63)	-(1.0)	-(1.0)
Zirconium	-	-	-	-	-	-	-

+ analysis by emission spectrography

# result not available

NB Numbers in parenthesis give the results of atomic absorption analysis

APPENDIX 4

A.1.a Cont'd

Material Liquid Aluminum Sulphate

Trace Metals (ppm as metal)+	AC25	AC26	AC27	AC28	AC29	AC30
Aluminum	- #	-	-	-	-	-
Antimony	-	-	-	-	-	-
Arsenic	-	-	-	-	-	-
Barium	-	-	-	-	-	-
Beryllium	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.06)
Bismuth	-	-	-	-	-	-
Boron	-	-	-	-	-	-
Calcium	-(142)	-(182)	-(93.5)	-(176)	-(72.6)	-(208)
Cadmium	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)
Chromium	-(51)	-(49)	-(41)	-(47)	-(46)	-(46)
Cobalt	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)
Copper	-(1.15)	-(1.49)	-(1.63)	-(1.26)	-(1.56)	-(0.96)
Gallium	-	-	-	-	-	-
Germanium	-	-	-	-	-	-
Indium	-	-	-	-	-	-
Iron	-(755)	-(700)	-(621)	-(1290)	-(1050)	-(691)
Lead	-(0.60)	-(0.88)	-(<0.6)	-(<0.06)	-(0.6)	-(2.63)
Magnesium	-(40.1)	-(62.4)	-(25.8)	-(45.7)	-(33.4)	-(55.3)
Manganese	-(40.1)	-(15.1)	-(8.91)	-(12.8)	-(8.47)	-(10.5)
Mercury	-(0.0006)	-(0.00049)	-(0.00037)	-(0.00037)	-(0.00063)	-(0.00044)
Molybdenum	-	-	-	-	-	-
Nickel	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.75)	-(0.5)	-(0.62)
Silicon	-	-	-	-	-	-
Silver	-	-	-	-	-	-
Strontium	-(0.99)	-(0.95)	-(0.81)	-(1.17)	-(0.68)	-(1.13)
Tellurium	-	-	-	-	-	-
Tin	-	-	-	-	-	-
Titanium	-(85.9)	-(82.2)	-(68.2)	-(62.7)	-(72.9)	-(58.2)
Vanadium	-(23.6)	-(24.3)	-(20.1)	-(25.4)	-(27.8)	-(19.7)
Zinc	-(1.1)	-(1.9)	-(0.75)	-(1.5)	-(1.1)	-(0.75)
Zirconium	-	-	-	-	-	-

** matrix

+ analysis by emission spectrography

# result not available

NB Numbers in parenthesis give the results of atomic absorption analysis

APPENDIX 4

A.1.b TRACE METALS IN SAMPLES OF SOLID ALUMINUM SULPHATE AND LIQUID FERRIC CHLORIDE DELIVERED TO SELECTED WATER TREATMENT PLANTS.

Material	Solid Aluminum Sulphate				Liquid Ferric Chloride
Trace Metals ppm (as metal)+	AC14	AN4	AN5	AC15	FC7
Aluminum	**	**	**	**	*
Antimony	-#	-	-	-	-
Arsenic	-	-	-	-	<60
Barium	-	-	-	-	<20
Beryllium	-(<0.03)	-(<0.03)	-(<0.03)	-(<0.03)	<20
Bismuth	-	-	-	-	<20
Boron	-	-	-	-	20-60
Calcium	-(74)	-(5.4)	-(8.9)	-(103)	*
Cadmium	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)	<20 (-)
Chromium	-(75)	-(0.41)	-(0.47)	-(72)	tr-<20
Cobalt	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)	*
Copper	-(1.8)	-(1.7)	-(1.4)	-(1.5)	tr-<20
Gallium	-	-	-	-	<20
Germanium	-	-	-	-	<20
Indium	-	-	-	-	*
Iron	1530	0.82	42.3	1100.0	**
Lead	-(13.1)	-(<0.6)	-(<0.6)	-(17.8)	<20
Magnesium	-(28)	-(5.0)	-(9.3)	-(25)	*
Manganese	-(12.7)	-(3.8)	-(4.3)	-(9.3)	*
Mercury	-(<0.01)	-(0.03)	-(<0.01)	-(<0.01)	-(0.01)
Molybdenum	-	-	-	-	<20
Nickel	-(<0.5)	-(1.0)	-(<0.5)	-(0.63)	20-60
Silicon	-	-	-	-	-
Silver	-	-	-	-	tr-<20
Strontium	-(2.4)	-(0.18)	-(0.25)	-(1.2)	*
Tellurium	-	-	-	-	<20
Tin	-	-	-	-	<20
Titanium	-(136)	-(3.08)	-(3.77)	-(52.8)	*
Vanadium	-(38.2)	-(3.86)	-(4.05)	-(31.3)	<20
Zinc	-(3.5)	-(0.25)	-(<0.25)	-(1.5)	-
Zirconium	-	-	-	-	<20

* interference

** matrix

NB Numbers in parenthesis give the results of atomic absorption analysis

+ analysis by emission spectrography

# result not available

tr = trace

APPENDIX 4

A.2.a PHYSICAL PROPERTIES OF SAMPLES OF LIQUID ALUMINUM SULPHATE DELIVERED TO SELECTED WATER TREATMENT PLANTS.

ANALYSIS

Sample	Specific Gravity @ 20°C	Percent Free Acid	Percent Free Al_2O_3	Colour/ Turbidity Hazen Units	Turbidity FTU	pH	
						U*	1%**
AC11	1.331	-	0.10	120 (green/blue opalescent)	55	2.18	3.21
AC12	1.335	-	0.18	200 (green/blue opalescent)	55	2.28	3.56
AN3	1.340	-	0.38	120 (clear beige)	30	2.41	3.58
AC13	1.330	-	0.13	140 (green/blue opalescent)	50	2.15	3.14
AB2	1.329	0.25	-	25 (clear, beige)	10	1.10	3.19
AB3	1.326	1.19	-	40 (clear, beige)	20	0.61	2.80
AB4	1.306	0.85	-	25 (clear, beige)	10	0.8	2.85
AB5	1.325	1.23	-	50 (clear, beige)	20	0.50	2.70
AB6	1.320	-	0.08	50 (clear, beige)	10	2.18	3.23
AC16	1.335	-	0.18	200 (green/blue) opalescent)	55	2.28	3.56
AC17	1.339	-	0.13	210 (green/blue opalescent)	55	2.25	3.56

APPENDIX 4

A.2.a Cont'd

ANALYSIS

Sample	Specific Gravity @ 20°C	Percent Free Acid	Percent Free Al_2O_3	Colour/ Turbidity Hazen Units	Turbidity FTU	pH	
						U*	1%**
AC18	1.328	-	0.17	290 (green/blue clear)	65	2.25	3.62
AN6	1.325	-	0.28	50 (clear, beige)	20	2.5	3.87
AC19	1.334	-	0.17	240 (green/yellow turbid)	60	2.24	3.61
AC20	1.338	-	0.15	200 (blue/green opalescent)	55	2.21	3.49
AC21	1.338	-	0.16	210 (light blue turbid)	50	2.22	3.49
AC22	1.325	-	0.16	170 (green/blue clear)	40	2.25	3.54
AC23	1.335	-	0.17	180 (green/blue clear)	55	2.23	3.59
AC24	1.335	-	0.16	170 (green/blue clear)	50	2.27	3.56
AC25	1.328	-	0.11	190 (green/blue clear)	60	2.15	3.15
AC26	1.333	-	0.01	>500 (green/blue very turbid)	225	1.5	3.30

APPENDIX 4

A.2.a Cont'd

ANALYSIS

Sample	Specific Gravity @ 20°C	Percent Free Acid	Percent Free Al_2O_3	Colour/ Turbidity Hazen Units	Turbidity FTU	pH U*	 1%**
AC27	1.330	-	0.13	200 (blue/green turbid)	55	2.14	3.00
AC28	1.331	-	0.10	190 (blue/green opalescent)	60	2.17	3.20
AC29	1.332	-	0.07	290 (green/blue turbid)	70	2.15	3.20
AC30	1.334	-	0.09	220 (green/blue clear)	70	2.20	3.55

* = undiluted coagulant
** = 1% solution of coagulant

APPENDIX 4

A.2.b. PHYSICAL PROPERTIES OF SAMPLES OF SOLID ALUMINUM SULPHATE AND LIQUID FERRIC CHLORIDE DELIVERED TO SELECTED WATER TREATMENT PLANTS

				ANALYSIS			
Sample	Specific Gravity @ 20°C	Percent Free Acid	Percent Free Al_2O_3	Colour/ Turbidity Hazen Units	Turbidity FTU	pH U*	pH 1%**
Solid Aluminum Sulphate							
AC14	-	-	0.12	-	-	-	3.48
AN4	-	-	0.47	-	-	-	3.55
AN5	-	-	0.69	-	-	-	3.76
AC15	-	-	0.31	-	-	-	3.52
Liquid Ferric Chloride							
FC7	1.406	-	-	-	-	-	2.09

* = undiluted coagulant
** = 1% solution of coagulant

APPENDIX 4

A.3. GAS CHROMATOGRAPHY ANALYSIS OF METHYLENE CHLORIDE EXTRACTS OF PRIMARY COAGULANTS FROM SELECTED WATER TREATMENT PLANTS.

Chemical	2,4-DNT[1] (ppm)	2,6-DNT[2]	TNT[3] & Unknowns (ppm)
Sample			
Liquid Aluminum Sulphate			
AC6	ND*	ND	ND
AC7	ND	ND	ND
AC8	ND	ND	ND
AC17	0.03	ND	ND
AC18	ND	ND	ND
AC22	ND	ND	ND
Solid Aluminum Sulphate			
AC15	ND	ND	ND

* = not detected

1 = 2,4-dinitrotoluene

2 = 2,6-dinitrotoluene

3 = trinitrotoluene

APPENDIX 4

A.4.a. PERCENT MOISTURE AND LOSS ON IGNITION OF SAMPLES OF LIQUID ALUMINUM SULPHATE DELIVERED TO SELECTED WATER TREATMENT PLANTS

Sample	Percent Moisture @ 105°C	Percent Loss on ignition
AB2	61.0	10.9
AB3	64.0	9.0
AB4	63.0	8.9
AB5	62.0	9.5
AB6	61.0	11.7
AC16	60.0	11.2
AC17	59.0	11.9
AC18	59.0	11.9
AN6	61.0	11.3
AC19	60.0	11.6
AC20	60.0	11.2
AC21	60.0	11.2
AC22	60.0	11.6
AC23	58.0	12.6
AC24	60.0	11.6
AC25	60.0	11.2
AC26	60.0	11.2
AC27	63.0	10.4
AC28	60.0	11.2
AC29	60.0	11.2
AC30	62.0	10.6

APPENDIX 4

A.4.b. PERCENT MOISTURE AND LOSS ON IGNITION OF SAMPLES OF SOLID ALUMINUM SULPHATE AND LIQUID SODIUM ALUMINATE DELIVERED TO SELECTED WATER TREATMENT PLANTS.

Sample	Percent Moisture @ 105°C	Percent Loss on Ignition
Solid Aluminum sulphate		
AC14	30.0	14.0
AN4	27.0	16.1
AN5	21.0	19.0
AC15	26.0	17.0
Liquid Sodium aluminate		
NA1	50.0	2.4
Liquid Ferric chloride		
FC6	61.0	7.4
FC1	67.0	8.9
FC5	70.0	7.5
FC7	62.0	11.0

APPENDIX 4

A.5. INFRARED ANALYSIS OF METHYLENE CHLORIDE EXTRACTS AND DOC OF ALUMINUM SULPHATE AND FERRIC CHLORIDE DELIVERED TO SELECTED WATER TREATMENT PLANTS

Sample		DOC (ppm)	IR scan
Aluminum sulphate -	Lindsay	2.9	NA*
	Kenora	1.8	NA
	Toronto (R.C. Harris)	2.7	NA
Ferric chloride -	Scarborough (Easterly)	ND**	ND

* extraction not attempted, because DOC levels were low

** material too corrosive

APPENDIX 4

B.1. TRACE METALS IN SAMPLES OF VARIOUS TREATMENT AIDS DELIVERED TO SELECTED WATER TREATMENT PLANTS

Material Soda Ash

Trace Metals (ppm as metal)+	NC1	NC2	NC3	NC4	NC5	NC6
Aluminum	- #	-	-	-	-	-
Antimony	-	-	-	-	-	-
Arsenic	-	-	-	-	-	-
Barium	-	-	-	-	-	-
Beryllium	-(<0.6)	-(<0.6)	-(<0.06)	-(<0.06)	-(<0.06)	-(<0.06)
Bismuth	-	-	-	-	-	-
Boron	-	-	-	-	-	-
Calcium	-(17.1)	-(84.4)	-(1.03)	-(85.4)	-(27.4)	-(36.9)
Cadmium	-(<0.05)	-(<0.05)	-(<0.05)	-(<0.05)	- (0.05)	-(<0.05)
Chromium	-(0.09)	-(<0.06)	-(<0.06)	-(<0.23)	- (0.06)	-(<0.06)
Cobalt	-(<0.5)	-(<0.5)	-(<0.5)	-(<0.5)	- (0.5)	-(<0.5)
Copper	-(<0.6)	-(<0.6)	-(<0.6)	-(<0.6)	-(<0.6)	-(<0.6)
Gallium	-	-	-	-	-	-
Germanium	-	-	-	-	-	-
Indium	-	-	-	-	-	-
Iron	-(0.54)	-(<0.36)	-(0.73)	-(<0.36)	- (0.36)	- (0.64)
Lead	-(<0.6)	-(<0.6)	-(<0.6)	-(<0.6)	- (<0.6)	-(<0.6)
Magnesium	-(18.7)	-(8.53)	-(40.8)	-(15.9)	- (27.6)	-(35.1)
Manganese	-(<0.6)	-(<0.6)	-(<0.6)	-(<0.6)	- (<0.6)	-(<0.6)
Mercury	-(<0.01)	-(<0.01)	-(<0.01)	-(<0.01)	- (<0.01)	-(<0.01)
Molybdenum	-	-	-	-	-	-
Nickel	-(0.5)	-(<0.5)	-(<0.5)	-(0.62)	- (<0.5)	- (0.75)
Silicon	-	-	-	-	-	-
Silver	-	-	-	-	-	-
Strontium	-(0.32)	-(3.55)	-(0.41)	-(3.54)	- (0.48)	- (0.54)
Tellurium	-	-	-	-	-	-
Tin	-	-	-	-	-	-
Titanium	-(<1.25)	-(<1.25)	-(<1.25)	-(<1.25)	- (<1.25)	- (<1.25)
Vanadium	-(<1.25)	-(<1.25)	-(<1.25)	-(<1.25)	- (<1.25)	- (<1.25)
Zinc	-(<0.25)	-(<0.25)	-(<0.25)	-(<0.25)	- (<0.25)	- (<0.25)
Zirconium	-	-	-	-	-	-

+ analysis by emission spectrography

# result not available

NB Numbers in parenthesis give the results of atomic absorption analysis.

APPENDIX 4

B.1. Cont'd

Material	Unslaked Lime			Sodium Bicarbonate
Trace Metals (ppm as metal)+	LU2	LU3	LU4	NB2
Aluminum	400-1200	- #	-	-
Antimony	<40	-	-	-
Arsenic	<120	-	-	-
Barium	<12	-	-	-
Beryllium	-	-(<0.6)	-(<0.6)	-(<0.6)
Bismuth	-	-	-	-
Boron	-	-	-	-
Calcium	**	**	**	-(167)
Cadmium	<12 (1.6)	-(0.26)	-(0.14)	-(<0.05)
Chromium	<40.(23)	-(9.0)	-(4.8)	-(<0.12)
Cobalt	-(<1.0)	-(<0.5)	-(<0.5)	-(<0.5)
Copper	tr-<12(12)	-(11.5)	-(11.8)	-(<0.6)
Gallium	tr-<12.0	-	-	-
Germanium	<40	-	-	-
Indium	<12	-	-	-
Iron	∿4000	-(148)	-(337)	-(<0.36)
Lead	<12 (2.9)	-(<0.6)	-(<0.6)	-(<0.6)
Magnesium	400-20000	-(>3240)	-(>4170)	-(39.4)
Manganese	40-120	-(26.0)	-(59.6)	-(<0.6)
Mercury	<400	-(<0.01)	-(<0.01)	-(<0.01)
Molybdenum	<12 (7.8)	-	-	-
Nickel	<12 (2.6)	-(<0.5)	- (1.8)	-(<0.5)
Silicon	-	-	-	-
Silver	-	-	-	-
Strontium	400-1200	-(158)	-(109)	-(2.05)
Tellurium	<40	-	-	-
Tin	<40	-	-	-
Titanium	12-40	-(<1.25)	-(<1.25)	-(<1.25)
Vanadium	tr-<12	-(4.19)	-(5.02)	-(<1.25)
Zinc	-(9.3)	-(14.4)	-(23)	- (0.88)
Zirconium	<12	-	-	-

** matrix

+ analysis by emission spectrography

# result not available

NB Numbers in parenthesis give the results of atomic absorption analysis.

APPENDIX 4

B.2. INFRARED ANALYSIS AND DOC OF METHYLENE CHLORIDE EXTRACTS OF VARIOUS TREATMENT AIDS DELIVERED TO SELECTED WATER TREATMENT PLANTS.

Analysis	DOC (ppm)	IR Scan
Sample		
Unslaked lime - Toronto (R.C. Harris)	NA*	+**

* material not amenable to analysis
** extracted organics not identifiable

APPENDIX 4

C.1.a TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE ARNPRIOR WATER TREATMENT PLANT.

Material	Raw Water	Treated Water	Sludge
Trace Metals (ppm as metal)+			
Aluminum	0.08	0.12	2160.
Antimony	- #	-	-
Arsenic	<0.003	<0.003	-
Barium	0.02	0.02	1.4
Beryllium	<0.0003	<0.0003	<0.04
Bismuth	-	-	-
Boron	0.03	0.01	<0.2
Calcium	15	16.	81.
Cadmium	<0.001	<0.001	<0.04
Chromium	<0.001	<0.001	0.37
Cobalt	<0.001	<0.001	-
Copper	0.11	0.15	0.43
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	0.12	0.04	165.
Lead	<0.003	<0.003	0.79
Magnesium	2.8	3.0	52.
Manganese	0.024	0.003	36.
Mercury	-	-	-
Molybdenum	<0.002	<0.002	<0.12
Nickel	<0.003	<0.003	0.22
Silicon	-	-	-
Silver	-	-	-
Strontium	0.06	0.07	0.51
Tellurium	-	-	-
Tin	-	-	-
Titanium	<0.003	<0.003	8.8
Vanadium	<0.002	<0.002	0.33
Zinc	0.01	0.01	0.89
Zirconium	-	-	-

+ analysis by emission spectrography

# result not available

APPENDIX 4

C.1.b TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE CORNWALL WATER TREATMENT PLANT.

Material	Raw Water	Treated Water	Sludge
Trace Metals (ppm as metal)+			
Aluminum	0.18	0.22	
Antimony	- #	-	
Arsenic	<0.003	<0.003	
Barium	0.01	0.03	
Beryllium	<0.0003	<0.0003	
Bismuth	-	-	
Boron	0.01	0.06	
Calcium	15.	27.	
Cadmium	<0.001	<0.001	
Chromium	<0.001	<0.001	
Cobalt	<0.001	<0.001	
Copper	0.003	0.04	
Gallium	-	-	
Germanium	-	-	
Indium	-	-	
Iron	0.02	0.01	No
Lead	<0.003	<0.003	
Magnesium	2.0	5.2	Sample
Manganese	0.004	0.001	
Mercury	-	-	
Molybdenum	<0.002	<0.002	
Nickel	<0.003	<0.003	
Silicon	-	-	
Silver	-	-	
Strontium	0.05	0.14	
Tellurium	-	-	
Tin	-	-	
Titanium	<0.003	<0.003	
Vanadium	<0.002	<0.002	
Zinc	0.003	0.001	
Zirconium	-	-	

+ analysis by emission spectrography

# result not available

APPENDIX 4

C.1.c TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE HAWKESBURY WATER TREATMENT PLANT.

Material	Raw Water	Treated Water	Sludge
Trace Metals (ppm as metal)+			
Aluminum	0.16	0.08	917
Antimony	- #	-	-
Arsenic	<0.003	<0.003	-
Barium	0.01	0.01	0.31
Beryllium	<0.0003	<0.0003	<0.04
Bismuth	-	-	-
Boron	0.02	0.01	<0.2
Calcium	7.2	16.	18.
Cadmium	<0.001	<0.001	<0.04
Chromium	<0.001	0.001	0.96
Cobalt	<0.001	<0.001	-
Copper	0.006	<0.003	0.29
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	0.22	0.02	116
Lead	<0.003	<0.003	<0.25
Magnesium	1.8	2.0	22.
Manganese	0.02	0.01	3.9
Mercury	-	-	-
Molybdenum	<0.002	<0.002	0.16
Nickel	<0.003	<0.003	<0.2
Silicon	-	-	-
Silver	-	-	-
Strontium	0.04	0.06	0.15
Tellurium	-	-	-
Tin	-	-	-
Titanium	0.004	<0.003	4.2
Vanadium	<0.002	<0.002	0.42
Zinc	0.01	0.01	1.4
Zirconium	-	-	-

+ analysis by emission spectrography

# result not available

APPENDIX 4

C.1.d TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE KENORA WATER TREATMENT PLANT.

Material	Raw Water	Treated Water	Sludge
Trace Metals (ppm as metal)+			
Aluminum	<0.05	<0.05	530
Antimony	- #	-	-
Arsenic	<0.05	<0.05	0.37
Barium	<0.05	<0.05	-
Beryllium	<0.006	<0.006	-
Bismuth	0.1	0.1	-
Boron	<0.05	<0.05	-
Calcium	<15	<15	37.4
Cadmium	<0.01	<0.01	<0.02
Chromium	<0.01	<0.01	1.0
Cobalt	<0.01	<0.01	-
Copper	<0.05	<0.05	0.58
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	<0.05	<0.05	22
Lead	<0.05	<0.05	<0.4
Magnesium	4.1	4.3	12.7
Manganese	<0.01	<0.01	0.95
Mercury	-	-	-
Molybdenum	<0.03	<0.03	<0.12
Nickel	<0.05	<0.05	<0.24
Silicon	-	-	-
Silver	-	-	-
Strontium	<0.02	<0.02	-
Tellurium	-	-	-
Tin	-	-	-
Titanium	<0.05	<0.05	-
Vanadium	<0.03	<0.03	-
Zinc	<0.02	<0.02	1.5
Zirconium	-	-	-

+ analysis by emission spectrography

# result not available

APPENDIX 4

C.1.e TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE LINDSAY WATER TREATMENT PLANT.

Material	Raw Water	Treated Water	Sludge
Trace Metals (ppm as metal)+			
Aluminum	<0.05	0.23	203
Antimony	- #	-	-
Arsenic	<0.05	<0.05	0.32
Barium	<0.05	<0.05	-
Beryllium	<0.006	<0.006	-
Bismuth	<0.1	<0.1	-
Boron	<0.05	<0.05	-
Calcium	>15.	>15.	245
Cadmium	<0.01	<0.01	<0.02
Chromium	<0.01	<0.01	0.16
Cobalt	<0.01	<0.01	-
Copper	<0.05	<0.05	<0.05
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	<0.05	<0.05	25.
Lead	<0.05	<0.05	<0.4
Magnesium	6.1	5.8	23.
Manganese	<0.01	<0.01	1.6
Mercury	-	-	-
Molybdenum	<0.03	<0.03	<0.12
Nickel	<0.05	<0.05	<0.24
Silicon	-	-	-
Silver	-	-	-
Strontium	0.12	0.12	-
Tellurium	-	-	-
Tin	-	-	-
Titanium	<0.05	<0.05	-
Vanadium	<0.03	<0.03	-
Zinc	<0.02	<0.02	<0.2
Zirconium	-	-	-

+ analysis by emission spectrography

# result not available

APPENDIX 4

C.1.f TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE OTTAWA (BRITTANIA) WATER TREATMENT PLANT.

Material	Raw Water	Treated Water	Sludge
Trace Metals (ppm as metal)+			
Aluminum	0.21	0.09	
Antimony	- #	-	
Arsenic	<0.003	<0.003	
Barium	0.01	0.02	
Beryllium	<0.003	<0.003	
Bismuth	-	-	
Boron	0.01	0.03	
Calcium	6.5	34.0	
Cadmium	<0.001	<0.001	
Chromium	0.001	<0.001	
Cobalt	<0.001	<0.001	
Copper	0.01	<0.003	
Gallium	-	-	
Germanium	-	-	No
Indium	-	-	
Iron	0.15	0.04	
Lead	<0.003	<0.003	Sample
Magnesium	1.8	6.4	
Manganese	0.01	0.004	
Mercury	-	-	
Molybdenum	<0.002	<0.002	
Nickel	<0.003	<0.003	
Silicon	-	-	
Silver	-	-	
Strontium	0.04	0.17	
Tellurium	-	-	
Tin	-	-	
Titanium	<0.003	<0.003	
Vanadium	<0.002	<0.002	
Zinc	<0.002	<0.001	
Zirconium	-	-	

+ analysis by emission spectrography

# result not available

APPENDIX 4

C.1.g TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE SCARBOROUGH (EASTERLY) WATER TREATMENT PLANT.

Material	Raw Water	Treated Water	Sludge
Trace Metals (ppm as metal)+			
Aluminum	0.08	0.02	322
Antimony	- #	-	-
Arsenic	<0.003	<0.003	-
Barium	0.02	0.02	7.2
Beryllium	<0.0003	<0.0003	<0.04
Bismuth	-	-	-
Boron	0.03	0.03	<1.0
Calcium	34	39	1320
Cadmium	<0.001	<0.001	0.36
Chromium	<0.001	<0.001	1.1
Cobalt	<0.001	<0.001	-
Copper	0.15	0.05	4.0
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	0.11	0.01	3610
Lead	0.003	<0.003	<0.65
Magnesium	5.9	6.6	170
Manganese	0.005	0.001	13
Mercury	-	-	-
Molybdenum	<0.002	<0.002	<0.12
Nickel	<0.003	<0.004	0.8
Silicon	-	-	-
Silver	-	-	-
Strontium	0.16	0.17	5.3
Tellurium	-	-	-
Tin	-	-	-
Titanium	<0.003	<0.003	22
Vanadium	<0.002	<0.002	4.1
Zinc	0.001	0.003	11.0
Zirconium	-	-	-

+ analysis by emission spectrography

# result not available

APPENDIX 4

C.1.h TRACE METALS IN SAMPLES OF RAW AND TREATED WATER AND WATER PLANT SLUDGE FROM THE TORONTO (R.C. HARRIS) WATER TREATMENT PLANT.

Material	Raw Water	Treated Water	Sludge
Trace Metals (ppm as metal)+			
Aluminum	<0.05	0.11	2200
Antimony	- #	-	-
Arsenic	<0.05	<0.05	0.88
Barium	<0.05	<0.05	-
Beryllium	<0.006	<0.006	-
Bismuth	<0.01	<0.01	-
Boron	<0.05	<0.05	-
Calcium	>15	>15	2315
Cadmium	<0.01	<0.01	0.19
Chromium	<0.01	<0.01	3.5
Cobalt	<0.01	<0.01	-
Copper	<0.05	<0.05	1.5
Gallium	-	-	-
Germanium	-	-	-
Indium	-	-	-
Iron	<0.05	<0.05	1330
Lead	<0.05	<0.05	<0.4
Magnesium	7.0	6.8	680
Manganese	<0.01	<0.01	25.7
Mercury	-	-	-
Molybdenum	<0.03	<0.03	<0.12
Nickel	<0.05	<0.05	1.6
Silicon	-	-	-
Silver	-	-	-
Strontium	0.15	0.14	-
Tellurium	-	-	-
Tin	-	-	-
Titanium	<0.05	<0.05	-
Vanadium	<0.03	<0.03	-
Zinc	<0.02	<0.02	10.7
Zirconium	-	-	-

+ analysis by emission spectrography

# result not available

APPENDIX 4

C.1.i. MERCURY IN RAW AND TREATED WATERS FROM SELECTED WATER TREATMENT PLANTS

Plant		Mercury+ ppb
Arnprior	Raw	- #
	Treated	-
Cornwall	Raw	-
	Treated	-
Hawkesbury	Raw	-
	Treated	-
Kenora	Raw	0.05
	Treated	0.07
Lindsay	Raw	<0.03
	Treated	<0.03
Ottawa (Brittania)	Raw	-
	Treated	-
Scarborough (Easterly)	Raw	<0.05
	Treated	<0.05
Toronto (R.C. Harris)	Raw	<0.08
	Treated	<0.08

+ mercury analysis by flameless atomic absorption; detection limit 0.02 to 0.04 ppb

# result not available

APPENDIX 4

C.2. ANALYSIS FOR GENERAL CHEMICAL PARAMETERS IN RAW AND TREATED WATERS FROM EIGHT WATER TREATMENT PLANTS.

Parameter	pH	Hardness ppm $CaCO_3$	Alkalinity ppm $CaCO_3$	Iron ppm Fe	Chloride ppm Cl	Turbidity FTU	Conductivity umhos/cm	Dissolved Solids ppm
Plant								
Arnprior								
Raw	6.8	57	49	0.48	3	1.9	116	80
Treated	7.1	61	56	0.16	5	4.2	144	95
Cornwall								
Raw	7.5	126	92	0.08	27	0.68	300	200
Treated	7.6	130	88	0.04	29	0.46	306	200
Hawkesbury								
Raw	7.6	34	23	0.37	5	2.4	76	50
Treated	7.3	51	28	0.1	6	0.31	126	90
Kenora								
Raw	7.5	58	53	0.08	3	1.5	129	84
Treated	6.9	60	42	0.02	5	0.67	165	107
Lindsay								
Raw	7.8	187	161	0.07	15	2.2	385	250
Treated	7.7	195	157	0.01	22	1.3	425	275
Ottawa (Brittania)								
Raw	7.2	33	23	0.21	3	1.8	67	45
Treated	7.5	52	24	0.14	3	0.36	120	80
Scarborough (Easterly)								
Raw	8.2	134	95	0.16	27	2.9	329	215
Treated	7.9	134	86	0.04	29	0.47	329	215
Toronto (R.C. Harris)								
Raw	8.0	137	98	0.06	29	1.1	335	220
Treated	7.7	139	84	0.02	35	1.1	350	245

APPENDIX 4

C.3. DISSOLVED ORGANIC CARBON IN RAW AND TREATED WATERS FROM SELECTED WATER TREATMENT PLANTS

Plant		DOC ppm
Arnprior	Raw	4.2
	Treated	2.7
Cornwall	Raw	2.0
	Treated	1.9
Hawkesbury	Raw	5.8
	Treated	2.3
Kenora	Raw	8.8
	Treated	4.5
Lindsay	Raw	8.2
	Treated	7.5
Ottawa (Brittania)	Raw	5.8
	Treated	2.3
Scarborough (Easterly)	Raw	2.5
	Treated	2.1
Toronto (R.C. Harris)	Raw	2.2
	Treated	2.1

APPENDIX 4

C.4. PERCENT MOISTURE, LOSS ON IGNITION AND TOTAL CARBON IN SELECTED WATER PLANT SLUDGES

Parameter	Percent Moisture @105°C	Percent Loss on Ignition	Total Carbon, ppm
Plant			
Scarborough (Easterly)	97.0	0.909	-
Lindsay	99.7	0.045	2300
Kenora	99.8	0.058	490
Toronto (R.C. Harris)	-	1.3	5900

APPENDIX 4

C.5. INFRARED ANALYSIS OF METHYLENE CHLORIDE EXTRACTS AND WEIGHT OF EXTRACTABLE MATERIAL OF SLUDGES FROM SELECTED WATER TREATMENT PLANTS

Parameter	Weight of extract*	IR Scan
Plant		
Scarborough (Easterly)	11000	+
Lindsay	3500	+
Kenora	4	+
Toronto (R.C. Harris)	1780	+

+ = extracted organics not identifiable

* = mg/Kg dried weight of sludge

APPENDIX 4

D.1. GAS CHROMATOGRAPHY ANALYSIS OF METHYLENE CHLORIDE EXTRACTS OF HYDROFLUOROSILICIC ACID SUPPLIED TO SELECTED WATER TREATMENT PLANTS

Parameter	2,4-DNT[1] (ppm)	2,6-DNT[2] (ppm)	TNT[3] & Unknowns (ppm)
Sample			
BI 1	<1	ND*	ND
BI 2	<1	ND	ND
BI 3	<1	ND	ND
BI 4	1.2	ND	ND
BI 5	<1	ND	ND
BI 6	<1	ND	ND
BI 7	<1	ND	ND
BJ 1	<1	ND	ND
BJ 2	1.3	ND	ND
BJ 3	<1	ND	ND
BK 1	<1	ND	ND
BK 2	<1	ND	ND
BK 3	<1	ND	ND
BK 4	<1	ND	ND
BK 5	<1	ND	ND
BL 1	<1	ND	ND
BL 2	<1	ND	ND
BL 3	<1	ND	ND
BL 4	<1	ND	ND
BL 5	<1	ND	ND
BL 6	<1	ND	ND
CA 1	1.8	ND	ND
CA 2	<1	ND	ND
CA 3	<1	ND	ND
CA 4	1.0	ND	ND
CA 5	<1	ND	ND
CB 1	2.1	ND	ND
CB 2	<1	ND	ND
CB 3	<1	ND	ND
CB 4	<1	ND	ND
CB 5	<1	ND	ND
CA 6	<1	ND	ND

APPENDIX 4

D.1. (Continued)

Parameter	2,4-DNT[1] (ppm)	2,6-DNT[2] (ppm)	TNT[3] & Unknowns (ppm)
Sample			
CC 1	<1	ND*	ND
CC 2	<1	ND	ND
CC 3	<1	ND	ND
CC 4	<1	ND	ND
CC 5	<1	ND	ND
CC 6	<1	ND	ND
CD 1	<1	ND	ND
CD 2	<1	ND	ND
CD 3	<1	ND	ND
CD 4	<1	ND	ND
CD 5	<1	ND	ND
CD 6	<1	ND	ND
CE 1	<1	ND	ND
CE 2	<1	ND	ND
CE 3	<1	ND	ND
CE 4	<1	ND	ND
CE 5	<1	ND	ND
CE 6	<1	ND	ND
CE 7	<1	ND	ND
CF 1	<1	ND	ND
CF 2	<1	ND	ND
CF 3	<1	ND	ND
CF 4	1.3	ND	ND
CF 5	<1	ND	ND
CF 6	<1	ND	ND
CF 7	<1	ND	ND
CG 1	<1	ND	ND
CG 2	<1	ND	ND
CG 3	<1	ND	ND
CG 4	<1	ND	ND
CG 5	<1	ND	ND

* Not Detected
NB Detection Limit 1 ppb to 5 ppb.

1 = 2,4-dinitrophenol
2 = 2,6-dinitrophenol
3 = trinitrophenol

APPENDIX 5

HANDLING, STORAGE AND ON-SITE TESTING OF CHEMICALS USED IN THE TREATMENT OF DRINKING WATER

The information given in this Appendix is intended as a guide for the water plant operator or supervisor. Included with details regarding the recommended handling and storage procedures, are recommendations for testing procedures to be carried out on chemicals upon receipt at the water plant, along with the appropriate AWWA* Standard number. When ordering treatment chemicals, a request should be made that they conform to recommended AWWA* standards. Manufacturers should provide results of the testing for conformity with the specifications. Water plants should occasionally submit samples of chemicals received, for spot checking of specifications, to the Ministry of the Environment laboratories. Chemicals used in water treatment should contain no substances in quantities capable of causing injurious effects to the health of those consuming the water to which the chemical has been added.

1. PRIMARY COAGULANTS

A) ALUMINUM SULPHATE ($Al_2(SO_4)_3$). AWWA STANDARD B403-70.

Aluminum sulphate (liquid or solid) is used for coagulation.

1. LIQUID

Storage - Liquid alum should be stored in lined steel, stainless steel, lead**, rubber or plastic containers. Liquid alum should be shipped and stored at temperatures above -13.3°C; below this temperature the alum will crystallize out. Although it appears to redissolve if warmed, the alum will never subsequently remain permanently in solution and its suitability for treatment will be compromised.

---

* AWWA = American Water Works Association

** since lead may dissolve in aluminum sulphate, this may be the least desirable container type.

Precautions - Liquid alum is of low pH and corrosive; it is irritating to the skin; handling requires caution and the use of protective clothing and corrosion-resistant equipment.

Testing - The following visual and analytical tests should be carried out on liquid alums upon delivery at the plant.

a) Colour - alum should be beige or blue/green in colour. Alums which are bluish or bluish-green in colour are probably manufactured by the direct process; this process tends to produce alums with a higher trace metal content. Colour should be measured with a Hach DR2 spectrophotometer. The reading for colour using this instrument is actually colour/turbidity since the latter interferes with the measurement of the former.

b) Turbidity - liquid alum should be sufficiently clear to enable flow-measuring devices to be read without difficulty. Alums with turbidity measured on a Hach DR2 spectrophotometer exceeding 200 FTU should be regarded as unsatisfactory.

c) Undiluted pH and pH of 1% solution - excessively low pH in liquid alum could cause treatment problems, especially in low alkalinity waters; the pH of a 1% solution, should thus be measured to determine if it is significantly different from previous shipments.

Specifications. Manufacturers specifications should include results of the following tests; the AWWA specifications are given in parenthesis:

- o Available water soluble aluminum Al (not less than 4.25%).
- o Available water soluble aluminum as Al_2O_3 (not less than 8%).
- o Excess water soluble aluminum (at least 0.013%).
- o Total water soluble iron as Fe_2O_3 (no more than 0.35% based on 8% Al_2O_3).
- o Insoluble and Suspended Material (not to exceed 0.2%)

2. SOLID

Storage - Solid alum should be stored in a dry area, protected from moisture in sealed containers.

Precautions - Handling of solid alum requires caution and the use of dust masks.

Testing:

a) The size of solid alum is important whether it is to be dissolved or fed with a dry feeding machine. Sizing may be done with sieves, in which case 100% should pass through a 3" ring and 75% be retained on a 1/2" sieve (US standard Z23.1 - 1961).

Specifications. Manufacturers specifications should include results of the following tests; the AWWA specifications are given in parenthesis:

- o Available water soluble aluminum as Al (not less than 9%)
- o Available water soluble aluminum as Al_2O_3 (not less than 17%)
- o Excess water soluble aluminum (at least 0.026%). Total water soluble iron as Fe_2O_3 (no more than 0.75% based on 17% Al_2O_3).
- o Insoluble and suspended material (not to exceed 0.5%)

B) LIQUID FERRIC CHLORIDE ($FeCl_3$) AWWA STANDARD B407-83

Ferric chloride is used as a coagulant.

Storage - Liquid ferric chloride should be stored in lined steel, stainles steel or plastic or rubber containers; it is normally supplied as a 35-45% solution.

Precautions - Liquid ferric chloride is stain-producing, corrosive and irritating to eyes, lungs and skin. Protective clothing and corrosion-proof equipment is necessary during handling.

Testing -

a) Ferric chloride from new suppliers should be analysed for heavy metals; water plants should send samples to MOE Central Laboratories for analysis.

b) Turbidity - liquid ferric chloride should be sufficiently clear to enable flow-measuring devices to be read without difficulty.

Specifications. Liquid ferric chloride should contain from 32-47% $FeCl_3$ and 11-17% iron.

C) SODIUM ALUMINATE ($Na_2O.Al_2O_3$). AWWA STANDARD B405-60.

Sodium aluminate is used for coagulation and for corrosion and pH control.

Storage - The solid form may be stored in bags, the liquid in steel or plastic drums.

Precautions - The dust is harmful and protective masks should be used during handling. The chemical tends to cake, and is mildly corrosive when wet.

Testing -

Turbidity - solutions of sodium aluminate should be sufficiently clear to enable flow-measuring devices to be read without difficulty.

Specifications. Solid sodium aluminate should be dry clean and free from lumps and foreign contamination. Liquid sodium aluminate shall contain no suspended material in excess of that shown below. Manufacturers specifications should provide results of the following tests; the AWWA specifications are given in parenthesis:

A) Solid:

- o Insoluble material (not more than 10%).
- o Available, soluble $Na_2Al_2O_4$ (minimum 75%).
- o Causticity (in excess of that requested to combined with the Al_2O_3 but not more than 5% Na_2O).

B) Liquid:

- o Insoluble material (not more than 0.5%)
- o Available, soluble $Na_2Al_2O_4$ (minimum 75%).
- o Causticity (in excess of that required to combine with the Al_2O_3 but not more than 5% Na_2O).

2. TREATMENT AIDS

Contaminant concentrations in chemicals used as treatment aids are low, and not expected to contribute levels of concern to the treated water, especially in view of the low dosage and, for the most part, intermittent use. Testing of such chemicals upon receipt at water treatment plants is not necessary. However, storage and handling procedures are given below, along with the AWWA specifications and standard number for each chemical.

A)SODIUM CARBONATE (Na_2CO_3) SODA ASH AWWA STANDARD B201-80

Sodium carbonate is used for corrosion control, softening and as a coagulant aid.

Storage - Sodium carbonate in bags or drums, should be stored in a cool, dry area in sealed containers to minimize contact with moisture and air; if moisture is absorbed, the material will become lumpy and difficult to handle and dissolve.

Precautions - Not classified as dangerous but it is dusty and irritates the eyes, nose, lungs and skin; it is mildly corrosive if wet. Goggles and dust respirators are recommended for handling. Soda ash and lime should not be present together, since caustic soda (highly corrosive) may form on combination of the chemicals and moisture.

Specifications. Material should be free of dirt, rocks, twigs or other foreign materials. Manufacturers specifications should provide results of the following tests; the AWWA specifications are given in parenthesis.

- Density - light soda ash (0.5 - 0.8 gm/mL)
  - dense soda ash (0.9 - 1.1 gm/mL)
- Sodium carbonate (not less than 99% by weight Na_2CO_3)
- Sodium oxide (equivalent of not less than 57.9% Na_2O)
- Insoluble material (not to exceed 0.05%)

B) SODIUM BICARBONATE ($NaHCO_3$)

There are no AWWA Standards for sodium bicarbonate. It is used as an aid in coagulation and for corrosion control.

Storage - Sodium bicarbonate should be protected from moisture in plastic-lined bags and stored in a cool dry place.

Precautions - It should not be allowed to come into contact with aluminum, with which it reacts, otherwise no special handling precautions are necessary.

Specifications. Sodium bicarbonate as $NaHCO_3$ not less than 98.6%.

C) QUICKLIME AND HYDRATED LIME (CaO). AWWA STANDARD B202-77

Lime is used for pH and corrosion control and for softening.

Storage - Lime should be stored in a cool dry area in sealed containers to minimize contact with moisture and air; it is unstable if left out in the open in unsealed containers.

Precautions - Lime is not classified as a dangerous chemical, but goggles and dust respirators are recommended for handling. Lime and soda ash should not be present together as caustic soda may form if the chemicals combine in the presence of moisture. The chemical reacts with water when it is mildly corrosive and can burn the skin.

Specifications. Lime is supplied as lumps (density 897-1040 kg/m^3), pebbles (density 960-1024 kg/m^3) or granules (density 800-1120 kg/m^3). Manufacturers specifications should include the results of the following tests; the AWWA specifications are given in parenthesis:

- Available calcium oxide (quicklime not less than 80%, hydrated lime not less than 62%)
- Insoluble material (not more than 5%)
- Slaking test (quicklime shall produce at least a 10^{o}C rise in temperature in 3 minutes, and a maximum temperature within 20 minutes).
- Fluoride (such that the fluoride content in distributed water will not be increased more than 0.1 mg/L on lime treatment).

D) ACTIVATED CARBON

Activated carbon is used for taste and odour control, organics removal and for dechlorination.

1. POWDERED ACTIVATED CARBON. AWWA STANDARD B600-78

Storage - Powdered activated carbon should be stored in a fireproof building, stacked in rows with aisles between so that each individual bag is accessible for removal in case of fire. No other materials should be in the same building.

Precautions - Strict precautions to avoid contact with strong oxidizing agents (chlorine, hypochlorites, permanganate, ozone and peroxides) are necessary, and mixing with hydrocarbons may cause spontaneous combustion. Dust respirators should be used in handling, and electrical connections in feed rooms should be water tight and dustproof. When moist, activated carbon will absorb oxygen from the air, and appropriate safety measures should be observed when entering enclosed areas containing activated carbon. N.B. A carbon fire may be extinguished using a fine water spray or chemical foam; water jets will spread the smouldering particles.

Specifications. The material should be free of dilutents, either soluble or insoluble, and should not impart to the water any contaminants that exceed the limits of the Drinking Water Objectives when combined with levels already in the water. Manufacturers' specifications should include the results of the following tests; the AWWA standard is given in parenthesis:

- Moisture content (not to exceed 8% by weight at time of shipment).
- Apparent density (not less than 0.2 gm/mL nor greater than 0.75 gm/mL).
- Absorptive capacity
    - a) Iodine number (not less than 500)
    - b) Phenol value (not greater than 3.5)

N.B. Reduction of threshold odour or tannin absorption can be used to measure absorptive capacity. (Reduction of threshold odour by a sample, should be not less than 70% of that of a reference sample, and the tannin value not more than 10% greater).

2. GRANULAR ACTIVATED CARBON. AWWA STANDARD B604-74

Storage - Granular activated carbon should be stored in a cool dry area.

Precautions - Strict precautions should be taken to avoid contact with strong oxidizing agents (chlorine, hypochlorites, permanganate, ozone and peroxides); mixing with hydrocarbon may cause spontaneous combustion. When moist, an oxygen-depletion hazard may develop in confined areas.

Specifications. The material shall contain no soluble inorganic or organic substances that would render the treated water unfit for use, and should not impart to the water any contaminants that exceed the limits of the Drinking Water Objectives when combined with levels already in the water.

Manufacturers specifications should include the results of the following tests; the AWWA standard is given in parenthesis:

- o Moisture content (not to exceed 8% by weight at time of shipment).
- o Apparent density (not less than 0.36 gm/mL)
- o Abrasion resistance (retention of average particles size not less than 70% as determined by standard tests.
- o Absorptive capacity
  - a) Iodine number (not less than 500)

E) SODIUM HYDROXIDE (NaOH). AWWA STANDARD B501-80

Sodium hydroxide is used for pH and corrosion control.

1. ANHYDROUS SODIUM HYDROXIDE (CAUSTIC SODA)

Storage - Flake, ground, crystal or bead caustic soda should be stored in steel containers, fibreboard drums or polyethylene-lined bags, in a cool, dry area. Protection from moisture is essential, since it will be absorbed, generating heat.

Precautions - Caustic soda in all forms is extremely hazardous and full protective clothing including goggles, face shields, cotton clothing, rubber aprons, boots and gloves are essential. Dilution and dissolution result in heat-generation, and should be carried out with extreme caution to avoid boiling or splattering; emergency eyewash and shower facilities should be provided in the vicinity of handling areas. All personnel should be given detailed instructions on handling procedures.

Specifications. Caustic soda is a white to off-white opaque to translucent solid which rapidly absorbs moisture. Manufacturers' specifications should include the results of the following tests; the AWWA standard is given in parenthesis;

- Percent total alkalinity as Na_2O (74.4% minimum)
- Percent sodium hydroxide as NaOH (96% minimum)
- Percent carbonate as Na_2CO_3 (not more than 2%)

2. LIQUID SODIUM HYDROXIDE (CAUSTIC SODA)

Storage - Liquid caustic soda should be stored in glass or steel containers in a cool dry area.

Precautions - Caustic soda in all forms is extremely hazardous and full protective clothing, including goggles, face shields, cotton clothing, rubber aprons, boots and gloves are essential. Dilution results in heat-generation, and should be carried out with extreme caution, to avoid boiling or splattering; emergency eyewash and shower facilities should be provided in the vicinity of handling areas. All personnel should be given detailed instructions on handling procedures. The 50% NaOH begins to crystallize at $12^{O}C$, which can cause problems in Canadian winters.

Specifications. Caustic soda is available in liquid form in concentrations from 12% to 50% NaOH. Manufacturers' specifications should include the results of the following tests; the AWWA standard is given in parenthesis:

- o Percent total NaOH (at least 50%)

  N.B. In Canada, percent total NaOH should be as specified in the order.

3. FLUORIDATION CHEMICALS

Fluoridation chemicals are added for prophylactic purposes to prevent dental caries in consumers.

A) HYDROFLUOROSILICIC ACID (H_2SiF_6). AWWA STANDARD B703-71

Storage - Hydrofluorosilicic acid (fluosilicic acid) should be stored in a well-ventilated room in containers of structural carbon, Hastelloy C, Durimet 20 or such rubbers and plastics as recommended by the manufacturers.

Precautions - Since hydrofluorosilicic acid is very corrosive and harmful to the skin and eyes, protective clothing and eyewear are essential. Feed equipment should be the same as that specified for storage containers. Emergency showers should be available in the vicinity of handling areas.

Specifications. Hydrofluorosilicic acid should be clean and free of visible suspended matter, and generally contains from 20 to 30% H_2SiF_6. Manufacturers' specifications should include the results of the following tests; the AWWA specifications are given in parenthesis:

- o Heavy metals (mercury, lead, bismuth and copper expressed as lead) (not more than 0.020%)
- o Percent H_2SiF_6 by weight (between 20 and 30%).

B) SODIUM SILICOFLUORIDE (Na_2SiF_6). AWWA STANDARD B702-74

Storage - Fibre drums, paper bags or barrels may be used to store sodium silicofluoride in a cool dry place; it is hygroscopic and tends to lump, rendering use difficult.

Precautions - Sodium silicofluoride is poisonous if inhaled or swallowed and containers should be labelled appropriately. Dust respirators and goggles should be worn during handling and personnel should wash thoroughly after handling the material. Spills should be cleaned up immediately. Medical attention is required immediately if the solid chemical is ingested.

Specifications. Sodium silicofluoride is a white powder, and should contain no stones, sticks, paper or other foreign matter. It may contain an anti-caking agent if this will not interfere with its application to drinking water, and it is non-toxic and odourless. Manufacturers' specifications should include the results of the following tests; the AWWA specifications are given in parenthesis:

- Density (approximately 75 lb/cu. ft.)
- Standard sieve #40 (420 um) (at least 98% passing through)
- Standard sieve #325 (44 um) (less than 25% passing through)
- Sodium silicofluoride (Na_2SiF_8) (minimum 98% corresponding to approximately 59.4% fluoride ions)
- Insoluble matter (not to exceed 0.5%)
- Moisture (not to exceed 0.5%)
- Heavy metals (mercury, lead, bismuth and copper expressed as lead) (not more than 0.05%).

Note: Much of the material used to produce this Appendix was obtained from the AWWA Standards for the individual chemicals (American Water Works Association, 6666 West Quincy Avenue, Denver, Colorado, 80235).

These standards include such information as:

-Definition of the Standard and an outline of the basis for the purchase, and/or rejection of the chemical

-Description of the material, including impurities and size
-Sampling, packing, shipping and marking requirements for varioius chemicals.
-Testing methods to determine the quality of chemicals

A Wall Chart, listing common water treatment chemicals, chemical names and formulae, containers, precautions, uses etc. in abbreviated form is available from "Water and Pollution Control", 1450 Don Mills Road, Don Mills, Ontario M3B 2X7 at $5.00 each (bulk rates available).

APPENDIX 6

PROCEDURES FOR THE MANUFACTURE OF WATER TREATMENT PLANT CHEMICALS

Outlined in this appendix are the manufacturing processes for the water treatment chemicals discussed in this report. Although only brief descriptions are given, they serve to indicate what differences may exist between chemicals derived from different manufacturing processes and where possible sources of contaminants may be in the manufacturing process.

ALUMINUM SULPHATE

The manufacture of aluminum sulphate can be carried out either directly from various types of crude bauxite (raw aluminum ore) or from purified bauxite produced by the Bayer process.

Bauxites may differ considerably in texture and colour, depending on the types and amounts of minerals associated with them e.g. magnetite Fe_3O_4; hematite, Fe_2O_3; goethite, FeO(OH); siderite ($FeCO_3$); kaolinite ($H_4Al_2Si_2O_2$); ilmenite ($FeTiO_3$) etc. The various types of ores give rise to alums which vary in appearance, particularly in colour and turbidity.

Bauxite ores usually contain alumina in two different forms, the trihydrate ($Al_2O_3.3H_2O$) and the monohydrate ($Al_2O_3.H_2O$); the proportions in any given ore vary according to the geological age, local conditions of temperature and rainfall and bacteriological action. Trihydrate ores preponderate in the Americas, are easier to handle, and are more economical.

There are two common methods of manufacture for aluminum sulphate:

a) Aluminum Sulphate by the Direct Method

   1. Liquid

      The crude bauxite, predominantly trihydrate is crushed and placed in a digester, with sulphuric acid. Continuous, efficient mixing is applied and the exothermic reaction is allowed to go to completion. After tests for free acid and free alumina are carried out, the amount of free alumina present is adjusted (by addition of alumina or sulphuric acid) to 0.1%. The liquid alum is then filtered and stored. Alum produced by this process tends to be blue-green in colour, with a specific gravity of 1.335 containing about 0.2% iron oxide (Fe_2O_3).

2. Solid

Liquid alum prepared by the direct method is evaporated down until it will form solid slabs when it is transferred to flat, ridged tables and cooled. These slabs may then be crushed and screened to produce lump, granular or powdered alum, which is then bagged for shipment. This solid alum is cream-coloured and contains about 0.3% iron oxide (Fe_2O_3).

b) Aluminum Sulphate using the Bayer Process

1. Liquid

In the Bayer process, the bauxite is broken down to a treatable size and fed into a dissolver of super-heated caustic soda, under a pressure of about 100 PSI; aluminum oxide from the ore goes into solution, while the iron and many impurities remain in suspension. The caustic sodium aluminate is then diluted with water, the exothermic reaction maintaining the heat of the solution. When dilution is complete, the hot solution is pressure filtered to separate out the red mud containing impurities such as iron oxide, silica, titanium and the unsoluble double aluminates and silicates.

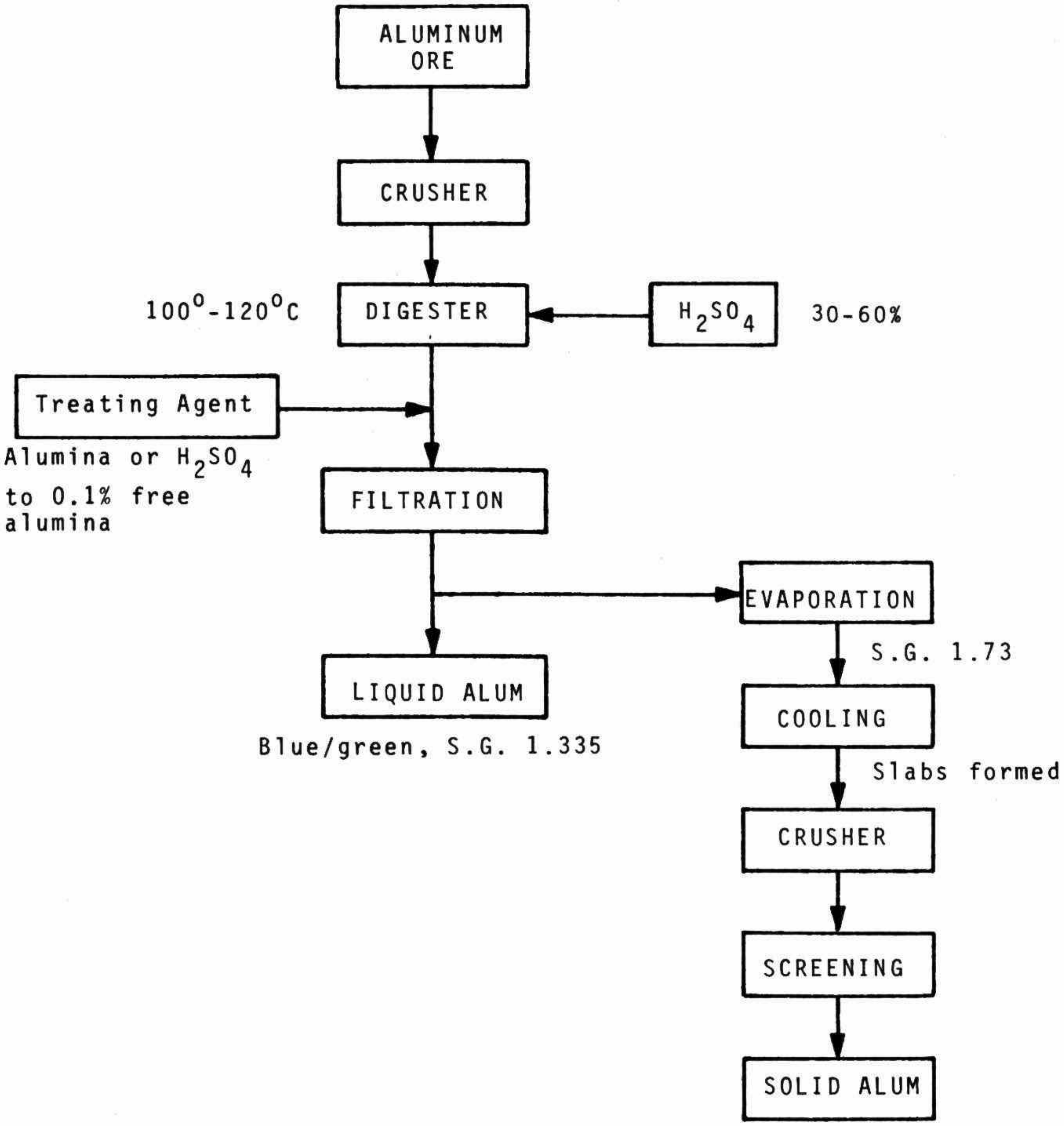
The filtered, super-saturated solution is transferred to a precipitator, where it is seeded with finely-divided pure crystalline alumina trihydrate, while being gently agitated. Approximately two thirds of the dissolved alumina crystallizes out as trihydrate, which is settled and filtered off. After washing and drying, the purified precipitate is treated with near-concentrated sulphuric acid to convert the trihydrate to liquid aluminum sulphate. The level of free acid or free alumina is checked, and sufficient pure powdered alumina or sulphuric acid is added to give a free alumina level of 0.1%. After clarification, the alum is stored for use. The product is clear beige, with an iron oxide content of less than 0.004%.

2. Solid Bayer Process Alum

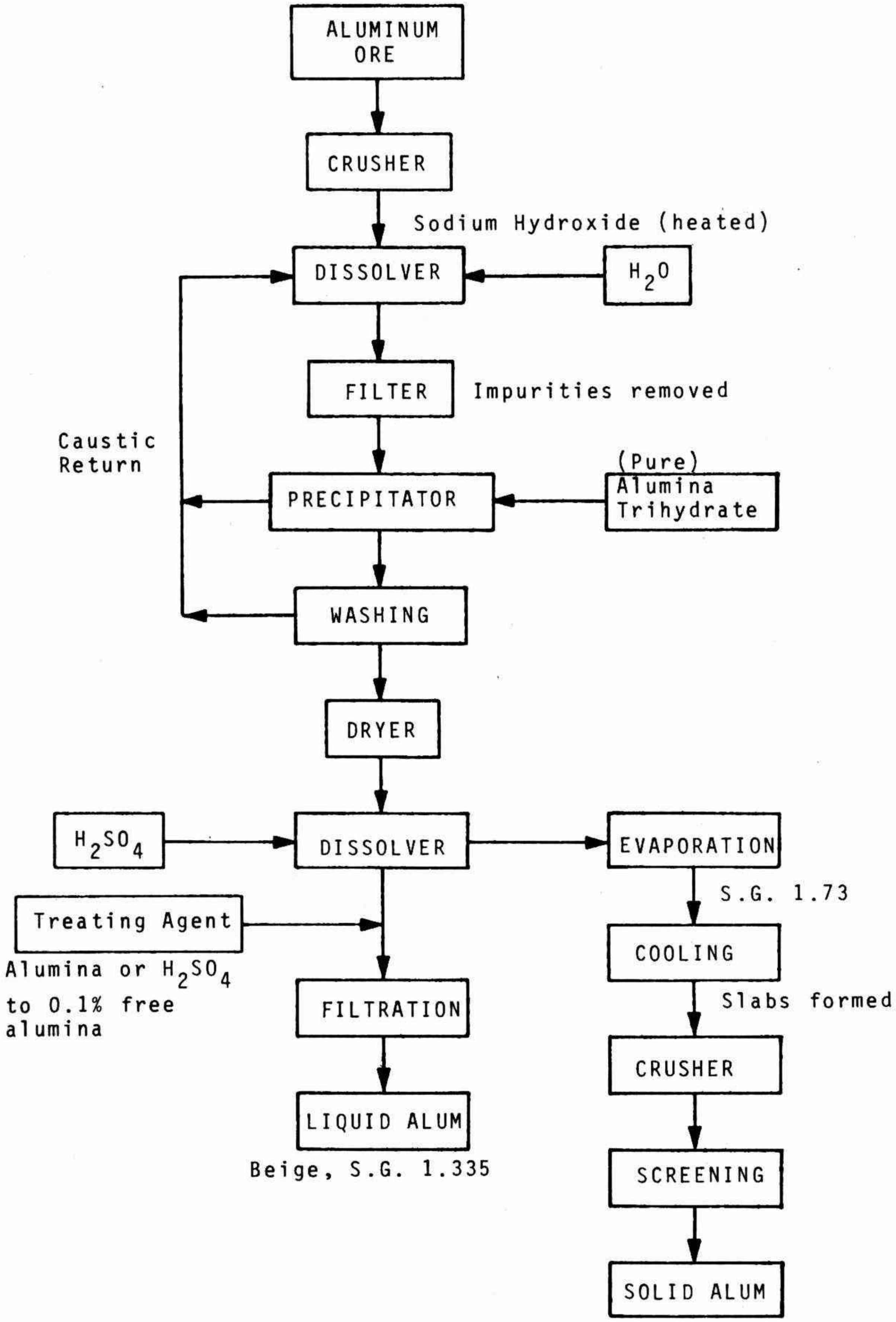
Purified liquid alum is evaporated down until, at specific gravity 1.73, it will solidify on flat ridged tables on cooling. The alum slabs are then crushed and screened to form lump, granular or powdered alum, which is then bagged for shipment. It is pure white with an iron oxide content of less than 0.004%.

N.B. It may be more economical under some circumstances to use kaolin clays (e.g. Georgia clay) as a substitute for bauxite. Although produced by essentially the same process, the substitution of the kaolin might contribute additional contaminants to the finished product.

ALUMINUM SULPHATE - DIRECT METHOD



ALUMINUM SULPHATE - BAYER PROCESS



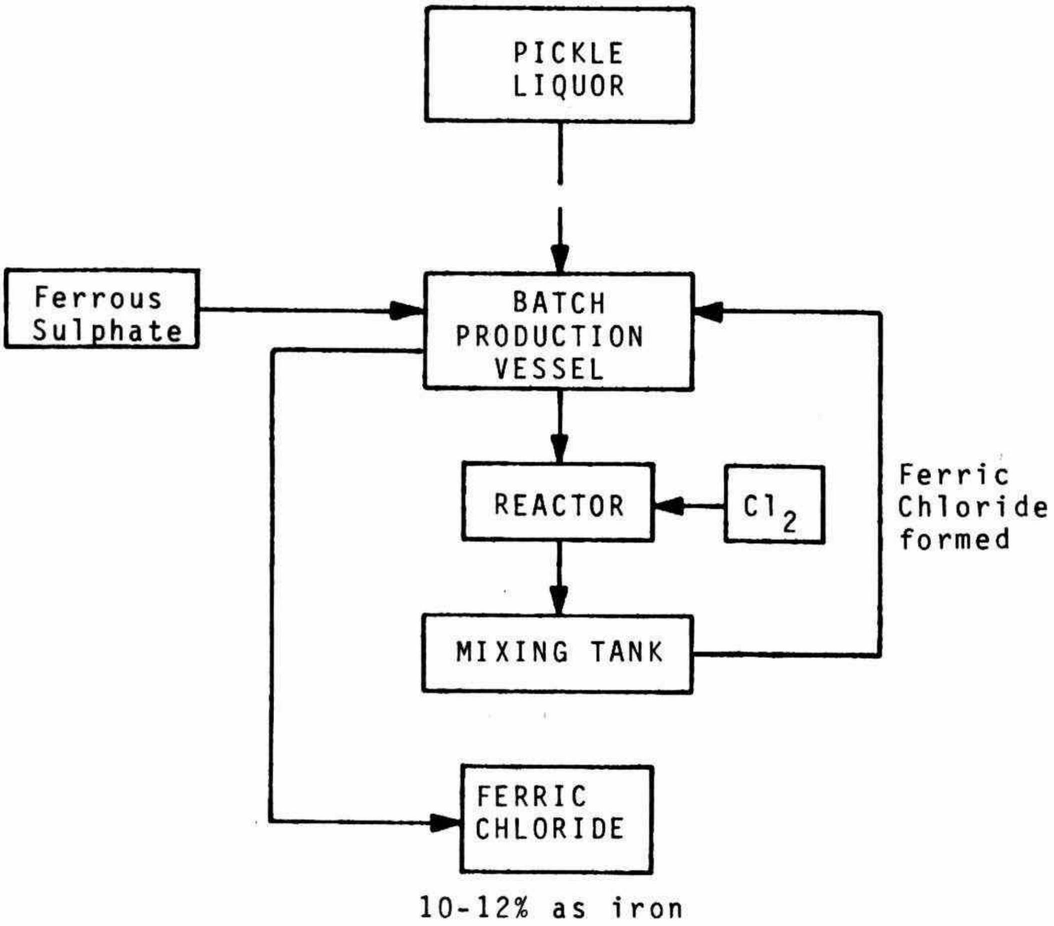
FERRIC CHLORIDE

Ferric chloride solution for use in water treatment is produced by reaction between gaseous chlorine and "pickle liquor". "Pickle liquor" results when rolled steel is cleaned with hydrochloric acid to remove rust.

In the production process, "pickle liquor" is fed into a batch production vessel. Discrete quantities are fed to a reactor tank where it is treated with chlorine gas then moved to a mixing tank. In the mixing tank, ferric chloride is formed but the reaction does not go to completion; a continuous recycling of the material back to the production vessel, the reactor tank and mixing tank, with further addition of chlorine is carried out, stepping up the ferric chloride content at each pass through the reactor and mixing tanks.

When reaction is complete, the iron level of the resultant ferric chloride solution is adjusted in the production vessel to the required strength of 10 to 12% as iron, by the addition of ferrous sulphate crystals. The adjusted solution may then be stored until required.

FERRIC CHLORIDE



SODIUM ALUMINATE

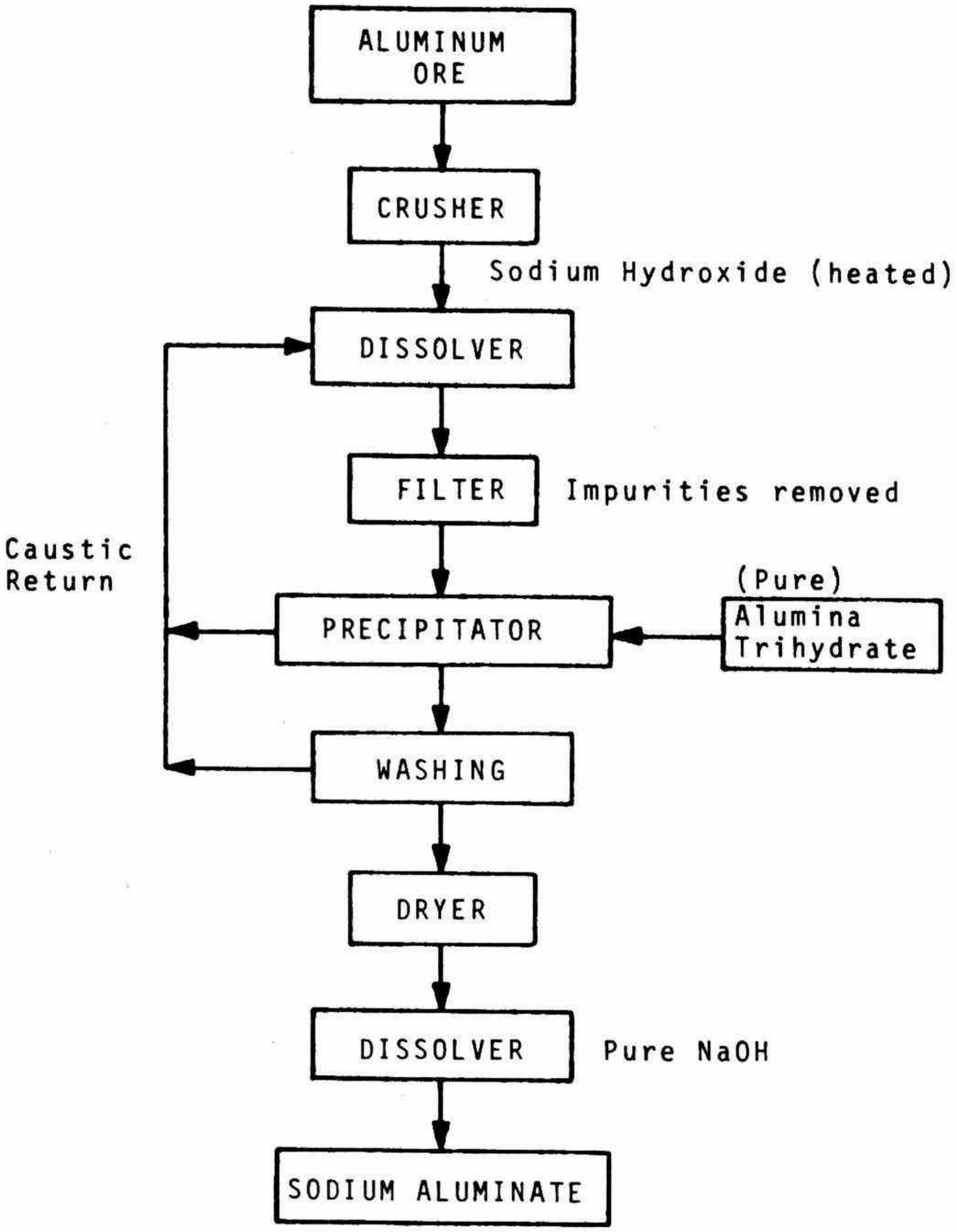
Several processes exist for the production of sodium aluminate. Sodium aluminate used in the water treatment industry is usually produced by the Bayer process (see aluminum sulphate) which yields an adequate quality product, although not as high in purity as that produced by other methods.

The crude aluminum ore (bauxite) is crushed and fed to a dissolver containing sodium hydroxide, and heated under pressure: greater temperatures and pressures are required to dissolve alumina from the monohydrate form than from the trihydrate. When the solution is complete, the red mud containing all the impurities is filtered out of the hot mixture.

The supersaturated aluminate is passed to a precipitator where it is cooled and finely divided, pure alumina trihydrate is added; this precipitates out the pure trihydrate; the sodium hydroxide "mother liquor" is returned to the dissolver.

The aluminum trihydrate is then washed, dried and redissolved in sodium hydroxide to produce pure liquid sodium aluminate, with a specific gravity of 1.52.

SODIUM ALUMINATE - BAYER PROCESS



SODIUM CARBONATE (SODA ASH)

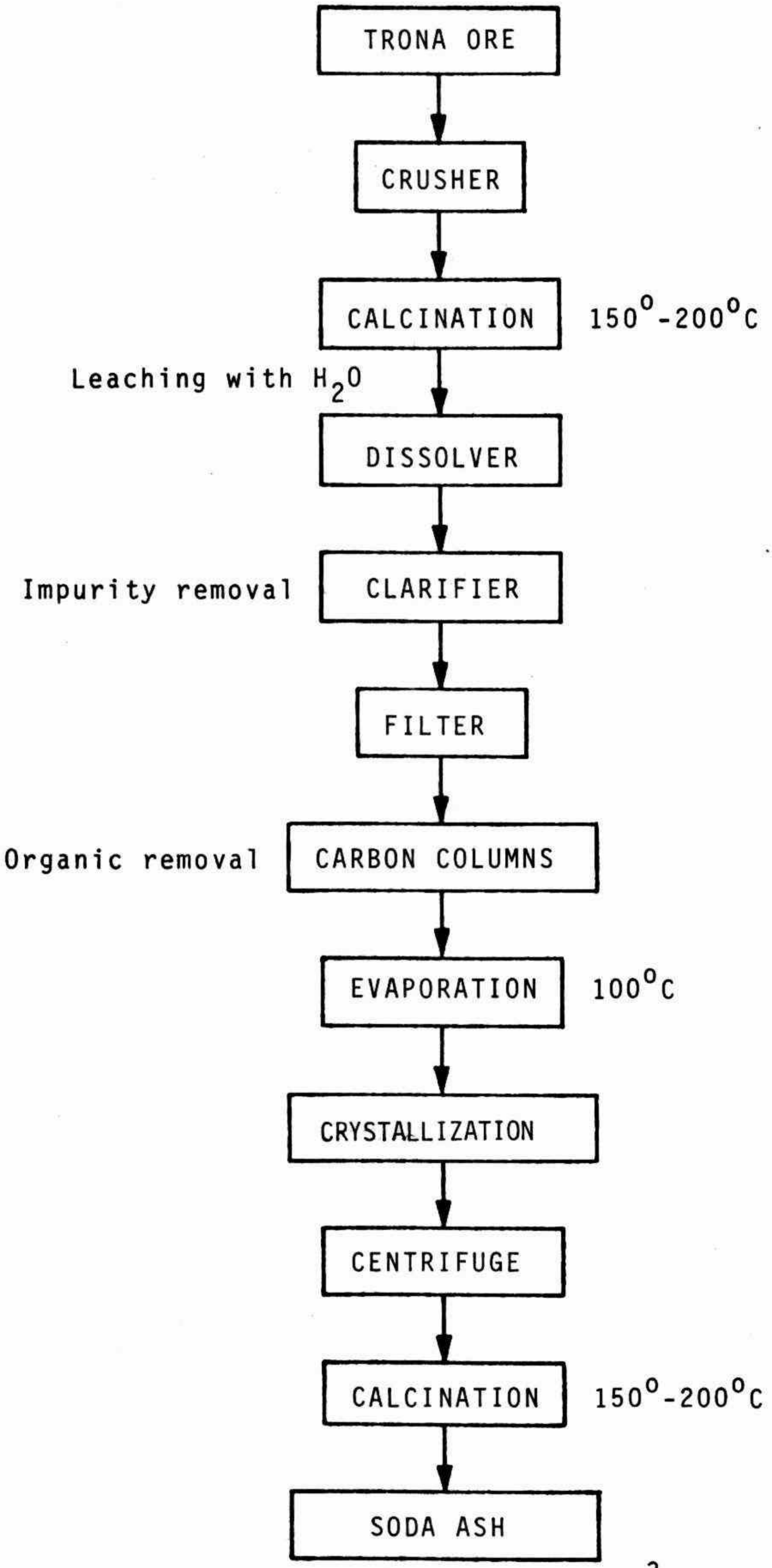
The commercial production of sodium carbonate is by treatment of the crude ore "trona" (approximately 95% sodium sesquicarbonate).

The bulk of soda ash is produced by the more economical "natural ash" or "monohydrate" process. The "trona" ore is first crushed, then calcined at 150°C to 200°C to break down the sesquicarbonate.

The crude soda ash is then leached with water and the resultant solution is then settled, clarified and filtered. Passage through carbon columns removes soluble organics and the clear carbonate liquor is then evaporated. Crystallisation must be carefully controlled in a series of evaporator units at 100°C, or the retrograde solubility of sodium carbonate causes the crystals to redissolve on cooling. The crystal slurry is concentrated by centrifuge, and the crystals are again calcined to produce pure anhydrous sodium carbonate.

Modifications in the manufacturing process can produce soda ash of varying bulk density; thus the 'monohydrate' process will produce a product with a bulk density of 50 lbs./ft^3. A 'synthetic' ash process yields soda ash of density 30 lbs./ft^3 and a product with a bulk density of 60 lbs./ft^3 can also be produced.

SODIUM CARBONATE (SODA ASH)

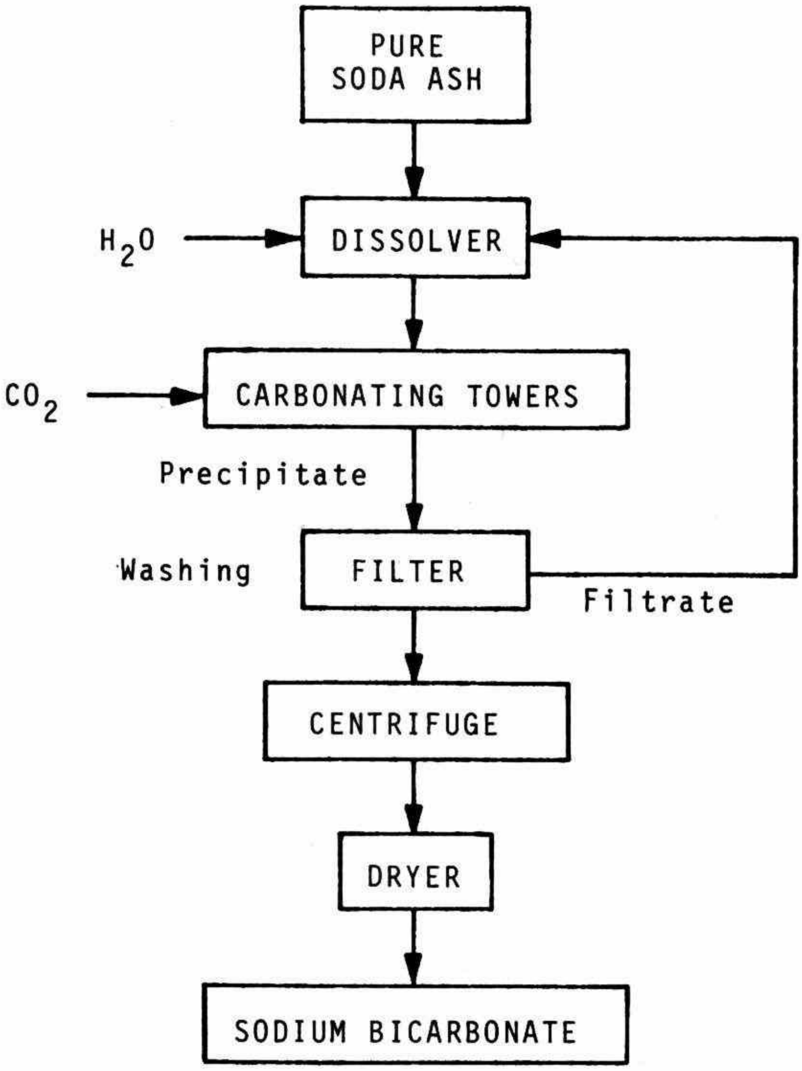


Bulk density - 50 lbs/ft^3

SODIUM BICARBONATE

Sodium bicarbonate is made by carbonating pure soda ash. A saturated solution of sodium carbonate, entering the top of a carbonating tower, reacts with carbon dioxide gas bubbling upward through the solution to form a suspension of bicarbonate. The precipitate is removed from the bottom of the tower, filtered and washed on a rotary drum filter. After centrifugation the material is dried, resulting in a product with a purity of 95% or greater.

SODIUM BICARBONATE



UNSLAKED LIME

Unslaked lime (quicklime) is obtained during the process of calcination, when limestone, which is composed of calcium and magnesium carbonate, decomposes thermally into lime (oxides of calcium and magnesium) and carbon dioxide.

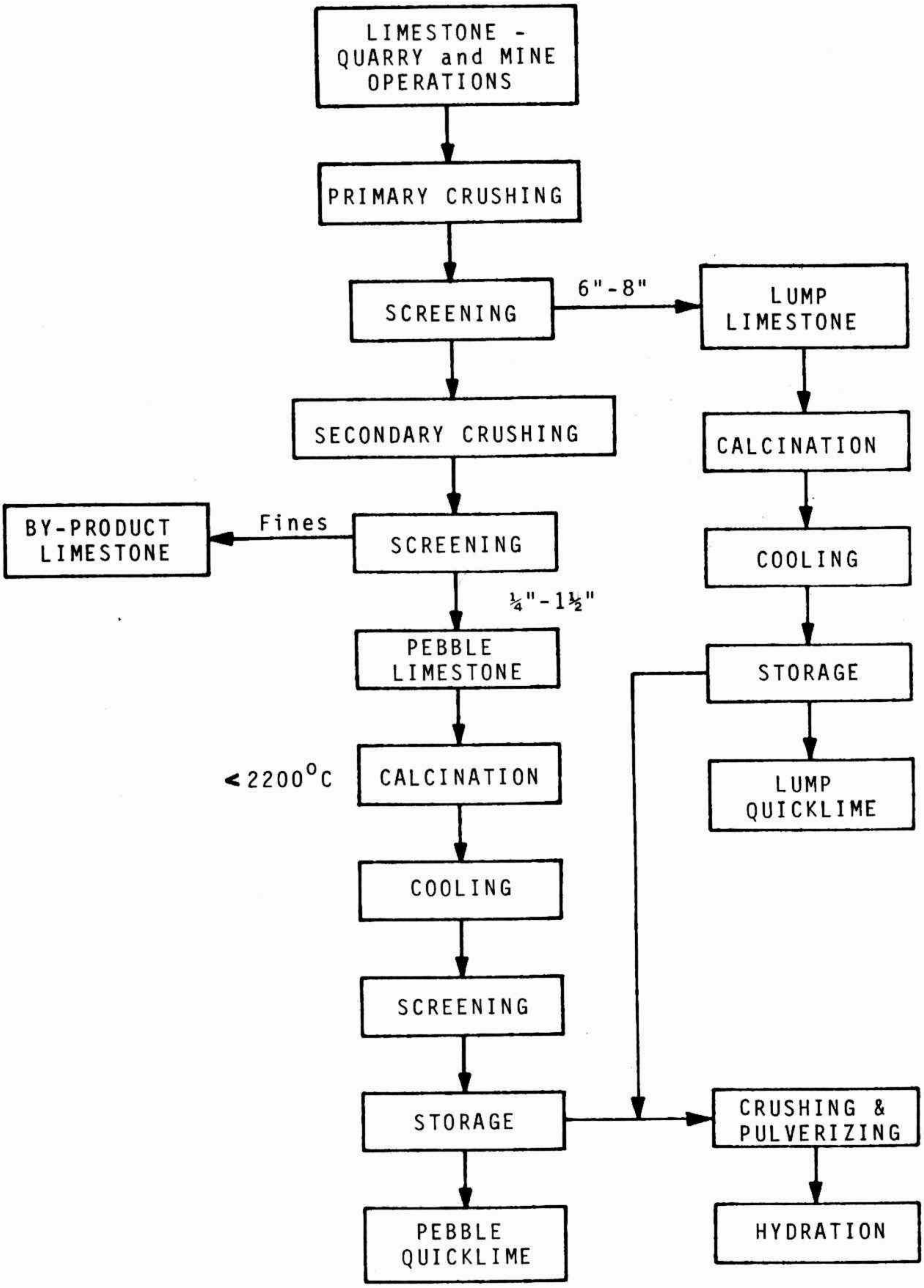
Limestone is crushed and then screened to separate large and small stone size. Coarse material with a diameter of 6"-8" (lump limestone) is conveyed to storage bins prior to calcination in vertical kilns. Smaller stones are further reduced in size by secondary crushing; pieces 1/4"-1 1/2" (pebble limestone) become lime-kiln feed. Pebble limestone, which yields pebble lime used at water treatment plants, is calcined in rotary kilns under carefully controlled conditions. The calcination temperature sequence may vary, but the temperature at the discharge end of the kiln is about 1900-2000^{o}C. Reaction time and temperature, as well as the rapid removal of by-product carbon dioxide, are factors critical to the production of a completely calcined but soft burned lime that is porous and chemically reactive. The product leaving the kiln is then cooled, screened for size and inspected, before being stored and shipped. Although most lime is sold as quicklime, hydrated lime can be produced by slaking, a process of treating lime with water, thereby converting the oxides to hydroxides.

Chemical lime is available in three forms depending on the type of limestone employed in manufacture:

- High Calcium - essentially calcium oxide and containing <5% magnesium oxide.
- Dolomitic - containing 30-40% magnesium oxide.
- Magnesian - containing 5-10% magnesium oxide.

The most common impurities naturally occurring in limestone are compounds of silica, alumina and iron. Since roughly two tonnes of limestone produce 1 tonne of lime, the percentage of impurities in quicklime is nearly double that of the original stone.

UNSLAKED LIME (QUICKLIME)



ACTIVATED CARBON

Activated carbon removes dissolved organics, chlorine and impurities causing colour, and taste and odour, from water by the process of adsorption, the attraction and accumulation of one substance to the surface of another. Major factors critical to the amount of adsorption are surface area, pore size, and pore distribution. The total pore area (surface area) of activated carbon ranges from 300 m^2/gm to 1800 m^2/gm, or 50 to 200 acres area per pound of carbon; however, the area available for adsorption is largely controlled by pore size. For example, a carbon with a pore area of 1300 m^2/gm and pore openings at the surface of only 20 Å diameter, would have a minimal capacity to adsorb material of 30 Å as any adsorption would be limited to the external surface of the particle. The greatest attraction occurs when the pores are barely large enough to admit the adsorbing molecules. Apart from the nature of the carbon itself, adsorption is also affected by: the nature of the material to be adsorbed (activated carbons have a preference for non-polar substances and substances of a higher molecular weight); the nature of the solution including its pH; and the treatment system and its mode of operation.

There are two distinct types of activated carbon. Liquid phase or decolourizing carbons are either low density, light, fluffy powders or hard granules; they have a trimodal distribution of pore radii, macropores, intermediate or transitional and micropores, giving the particle an open structure and allowing liquids access to the smaller pores. A significant frequency of pore radii 50 to 500 Å (intermediate pores) results in rapid adsorption of the smaller adsorbates and improved adsorption of the large adsorbates such as colloids. Gas phase carbons, which are vapour adsorbent, hard, dense granules, have mostly large and small pores with little pore volume in the intermediate range.

Activated carbon can be manufactured using a variety of raw materials including wood, coal, peat, sawdust, lignite and nut shells and can be

*Å = Angstrom units = 10^{-8} cm.

activated by physical or chemical means. Carbons utilized in water and wastewater treatment are activated by a high temperature, physical (oxidative) method consisting of three steps: 1. dehydration (of the raw material). 2. carbonization and 3. activation. There may be many modifications to this process depending on the raw material used and the end product desired. Often manufacturing is tailored to produce carbons that serve certain needs and possess specific adsorptive properties.
The product reviewed in this study, a powdered activated carbon made from wood, was formed by a thermal activation method similar to the following process:

- The raw material is dried at temperatures up to 170^{0}C to remove excess water and structural water.
- Carbonization involves three essential stages using reaction temperatures of approximately 170^{0}, 275^{0} and 400^{0}-600^{0}C to slowly heat the dried material in the absence of air causing decomposition with the formation of several by-products such as carbon monoxide, carbon dioxide, acetic acid, tar and methanol. The final stage will yield approximately 80% primary carbon.
- An activating agent, usually steam, is applied at temperatures of 750^{0}-950^{0}C removing tars and other decomposition products deposited in the pores during carbonization. Pores not containing deposits are exposed to the steam longer than the ones that are plugged with amorphous carbon. Further exposure to the activating agent results in widening the existing pores and development of the porous structure.
- Post activation processing includes: crushing, grinding, acid washing and water washing to remove extractable ash constituents, drying and packaging.

Activated carbons, whether powdered or granular, are categorized according to certain physical properties. There are several criteria by which carbons are judged and selected such as:

a) Adsorptive Capacity: Two simple tests of adsorptive capacity are the Iodine Number: the capacity of an activated carbon to remove iodine or substances of low molecular weight; and, the Molasses Number: a measure of the carbon's capacity for adsorption of colour or high molecular weight substances. The amount of iodine removed from solution by activated carbon has been found to be proportional to the surface area of pores having diameters greater than 10 Å while the decolourization of molasses can be correlated with surface area in pores with diameters greater than 28Å. No single adsorptive test can accurately determine the value of an activated carbon in all systems. Only "on-site" testing or "pilot" testing will reveal the value of a particular carbon as an adsorbent for a specific application.

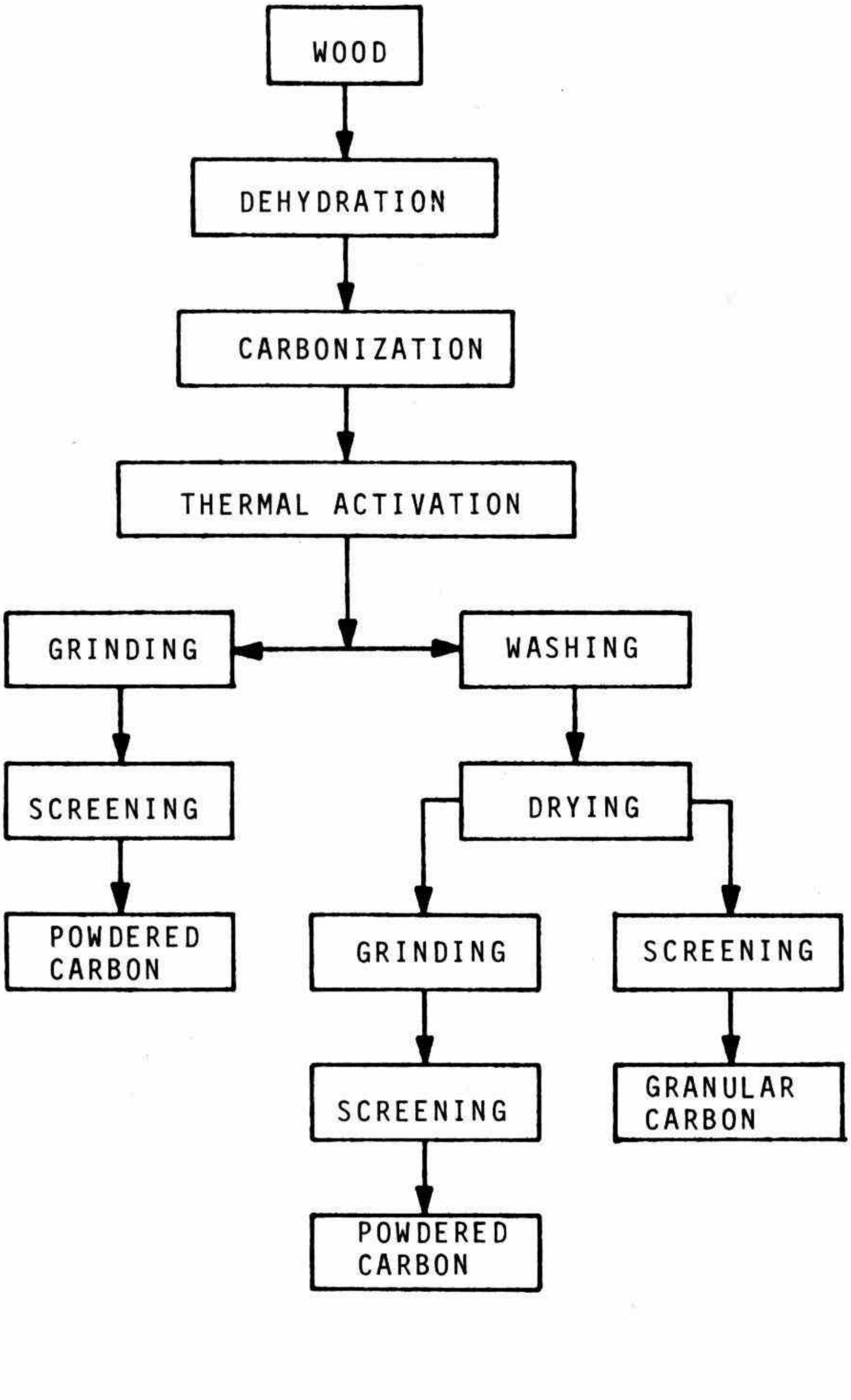
b) Apparent Density: The apparent density is the weight per unit volume of carbon and is expressed as pounds per cubic foot. A high density activated carbon occupies less volume and retains less liquid per unit volume than carbon of lower density.

c) Purity: Purity is measured by the amount of water solubles, acid solubles and ash the carbon contains and pH of the carbon.

d) Filterability: Powdered activated carbons that produce a good filtration rate with good filtrate clarity are considered to have good filterability. Particle size which is determined by sieve analysis and particle size distribution control the filtration characteristics of the carbon.

e) Resistance to Breakage: Resistance to breakage refers to properties of granular activated carbon that are measured by Abrasion Number and Hardness Number tests. High resistance to attrition means that the carbon can be readily regenerated and does not suffer undue damage during backwash.

ACTIVATED CARBON



SODIUM HYDROXIDE

Sodium hydroxide (caustic soda) and chlorine are co-produced by the mercury, diaphragm or membrane cell methods of electrolysing sodium chloride brine. Although the diaphragm cell has been most popular in North America in the past, the mercury cell is still used in some Canadian plants. Membrane cells, (some designs are in the early stages of commercial use), are now regarded as the best technology and most new plants are likely to use them. Mercury and membrane cell plants yield high purity, low chloride grade sodium hydroxide, whereas plants that utilize diaphragm cells supply a lower cost product which, for that reason, is used where purity is not essential.

Most of the caustic soda produced in Canada comes from the diaphragm cell process. Modern diaphragm cells have vertical electrodes. The anode and cathode compartments are divided by a porous diaphragm, a layer of asbestos fibre which covers the steel mesh cathode. All chloralkali cells require a brine free from impurities including calcium, magnesium and sulphates that affect cell operation. Purification involves the addition of sodium carbonate to remove calcium, sodium hydroxide to remove magnesium and iron, and a soluble barium or calcium salt to control the sulphate. Precipitates are allowed to settle, the brine (25% NaCl) is filtered, and its pH adjusted before it is pumped to the electrolytic cell. Purified brine flows into the anode compartment and remains at a level higher than that in the cathode compartment (patent: LeSueur). The difference in hydrostatic pressure causes a slow percolation rate through the diaphragm from one chamber to the other. A low percolation rate increases the concentration of the sodium hydroxide in the catholyte, while a high percolation rate decreases the cathode current efficiency.

Diaphragm Cell (Electrolysis) Process. When sodium chloride dissolves in water, it ionizes to give mobile sodium and chloride ions in the solution:

$$NaCl \qquad Na^+ + Cl^-$$

Direct current passes between the electrodes, through the brine, and causes the cations (Na^+) to move toward the negative electrode and the anions (Cl^-) to move toward the positive electrode. The reactions produced by electrolysis are represented by the following equations:

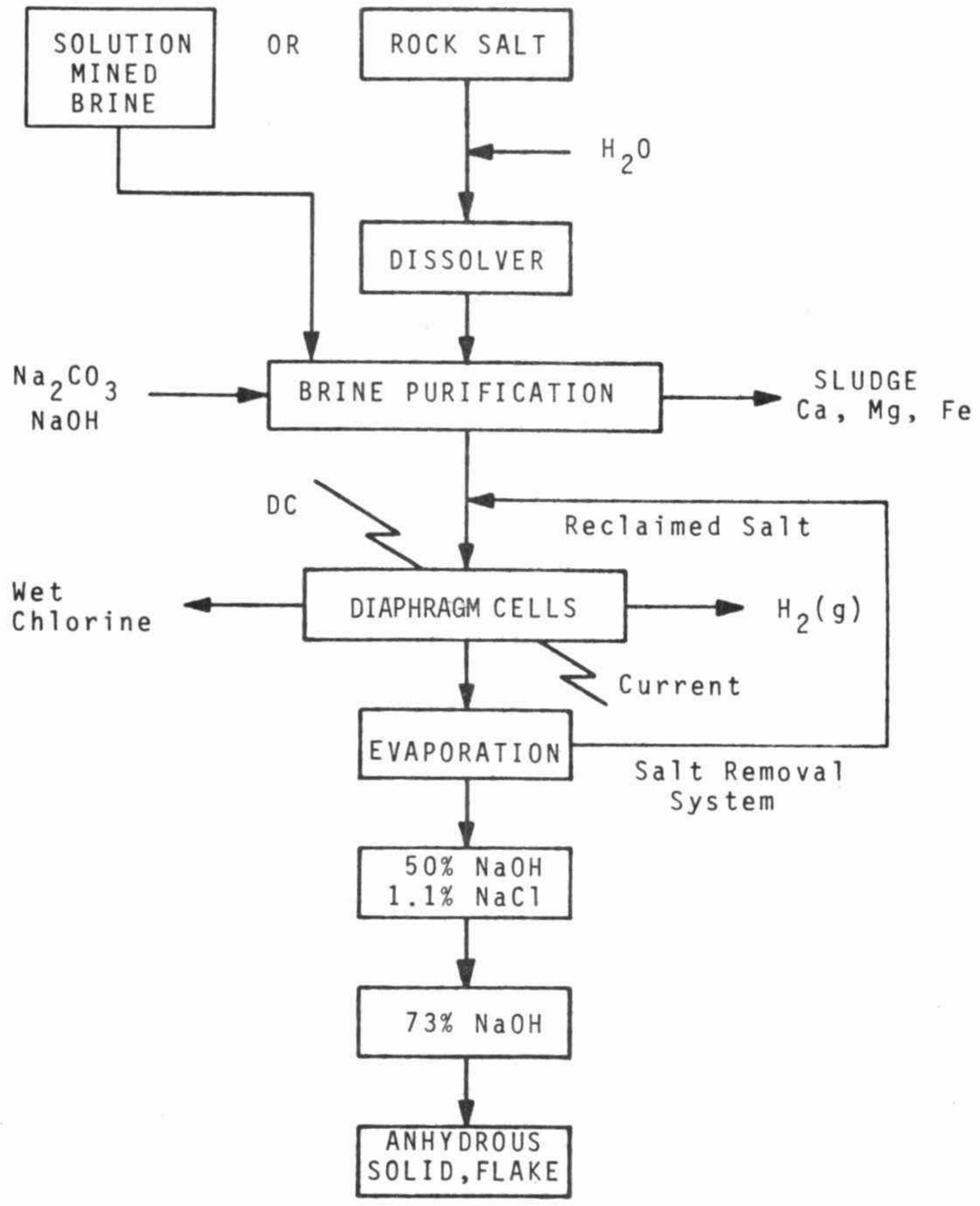
At the cathode $2Na^+ + 2H_2O + 2e \quad 2Na^+ + 2OH^- + H_2$
At the anode $2Cl^- + 2e \quad Cl_2$

The amount of caustic one cell can produce depends directly on the amount of D-C electric current passed through it; the voltage required depends on the type of cell, the cell design and the amount of current.

The resulting cell liquor containing 11% sodium hydroxide and 16% sodium chloride is then concentrated, using substantial amounts of process steam to evaporate the water and crystallize the salt, and the excess salt is reclaimed and returned to make more brine; however, the concentrated caustic retains about 1.1% sodium chloride as impurity. The sodium hydroxide may be further concentrated to a 73% solution, which may be used for water treatment, or dehydrated to a solid, anhydrous flake. Wet chlorine gas produced in the cell is cooled, dried, compressed and liquified. The hydrogen gas liberated at the cathode is also dried and purified.

SODIUM HYDROXIDE

DIAPHRAGM CELL PROCESS



HYDROFLUOROSILICIC ACID (FLUOSILICIC ACID), SODIUM SILICOFLUORIDE

a) Hydrofluorosilicic Acid

Hydrofluorosilicic acid is produced as a byproduct in the process of making phosphoric acid fertilizer.

Fluoro-silico-phosphate rock is crushed and fed to a reactor containing 93% sulphuric acid, producing a weak phosphoric acid solution containing suspended particles of gypsum; silicon tetrafluoride gas is released during the reaction.

The silicon tetrafluoride gas is passed into a scrubbing tower, where it reacts with continuously circulating water to form hydrofluorosilicic acid.

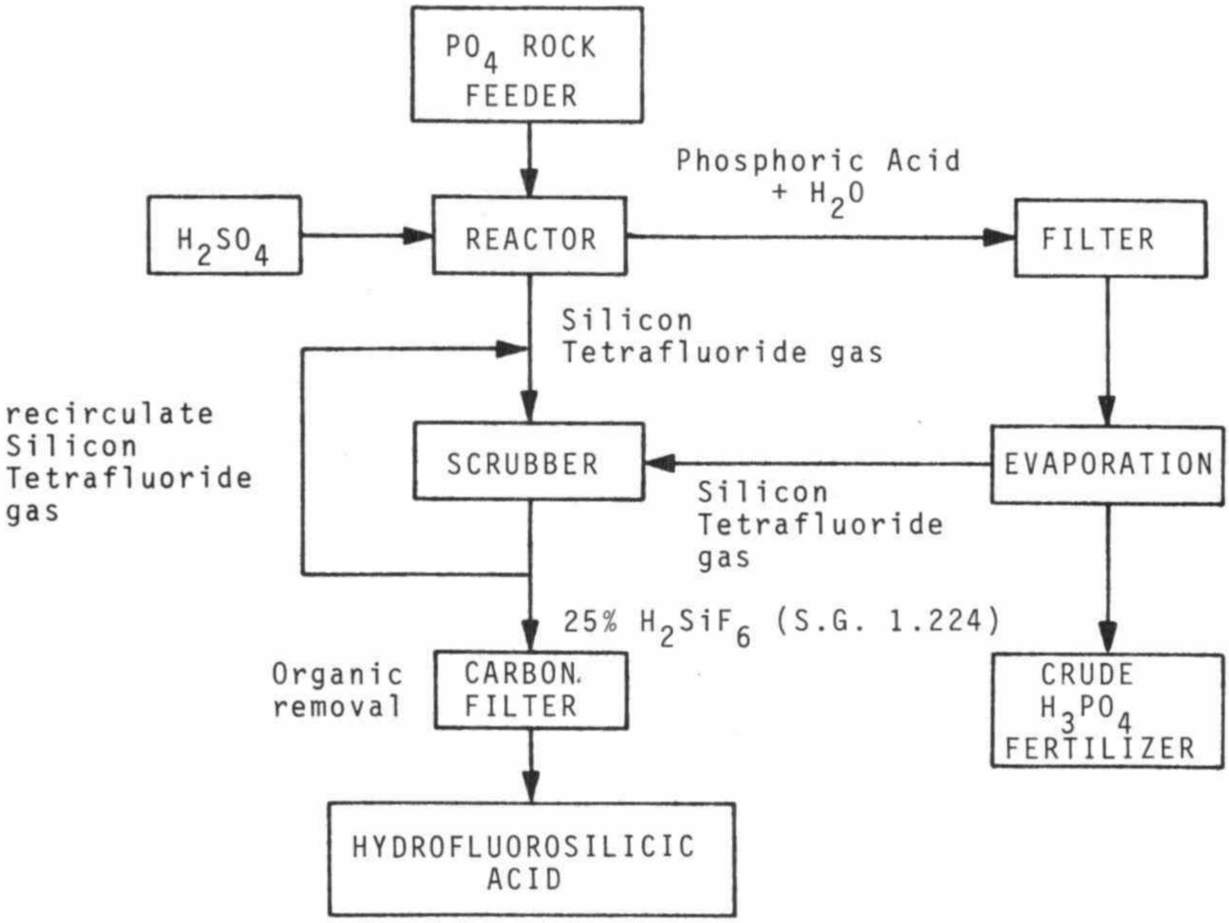
The weak phosphoric acid is filtered free of gypsum; the filter cake is washed with water and the washings are combined with the filtered phosphoric acid and the solution is pumped to an evaporator where the released silicon tetrafluoride/hydrofluorosilicic acid gases are diverted to the scrubbing tower.

When the concentration of hydrofluorosilicic acid in the circulating water in the scrubber reaches 25 ±1%, and a specific gravity of 1.224, it is passed through a carbon column to remove trace organics. The hydrofluorosilicic acid is then stored.

b) Sodium Silicofluoride

Sodium silicofluoride is formed on reaction of hydrofluorosilicic acid with sodium carbonate.

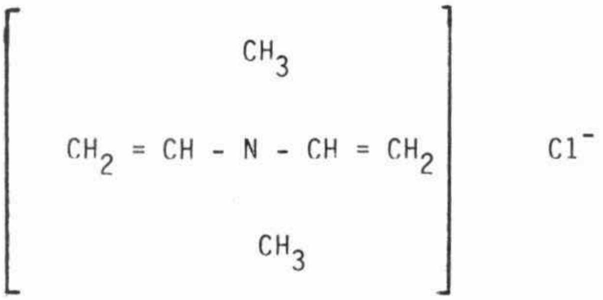
HYDROFLUOROSILICIC ACID



CAT FLOC T

A polymer is a macromolecule with an extremely large molecular weight made up of a large series of repetitions of small chemical units or molecules called monomers.

The monomer of Cat Floc T has the following configuration:



$$\left[\begin{array}{c} \mathrm{CH_3} \\ \mathrm{CH_2 = CH - N - CH = CH_2} \\ \mathrm{CH_3} \end{array}\right] \quad \mathrm{Cl^-}$$

with a molecular weight of 133.5, known as dimethyl diallyl ammonium chloride. This is placed in a pressure vessel at elevated temperature and an initiator chemical is added. This catalyses the polymerization reaction and the monomer molecules begin to link up or polymerize. The degree and manner of linkage is dependant on the time of the reaction, the pressure and the temperature.

The molecular weight of Cat Floc T lies between 250,000 and 600,000. It is a pale yellow liquid with a freezing point of 27°F (-2.8°C), and thus must be handled carefully during shipping and storage to avoid freezing.

3437g 1-100
3950g 101-146
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